between different members of the population produced the following results:

<table>
<thead>
<tr>
<th>Cross</th>
<th>Parents</th>
<th>Progeny</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>purple × blue</td>
<td>all purple</td>
</tr>
<tr>
<td>2</td>
<td>purple × purple</td>
<td>76 purple, 25 turquoise</td>
</tr>
<tr>
<td>3</td>
<td>blue × blue</td>
<td>86 blue, 29 turquoise</td>
</tr>
<tr>
<td>4</td>
<td>purple × turquoise</td>
<td>49 purple, 52 turquoise</td>
</tr>
<tr>
<td>5</td>
<td>purple × purple</td>
<td>69 purple, 22 blue</td>
</tr>
<tr>
<td>6</td>
<td>purple × blue</td>
<td>50 purple, 51 blue</td>
</tr>
<tr>
<td>7</td>
<td>purple × blue</td>
<td>54 purple, 26 blue, 25 turquoise</td>
</tr>
<tr>
<td>8</td>
<td>turquoise × turquoise</td>
<td>all turquoise</td>
</tr>
<tr>
<td>9</td>
<td>purple × blue</td>
<td>49 purple, 25 blue, 23 light-blue</td>
</tr>
<tr>
<td>10</td>
<td>light-blue × light-blue</td>
<td>60 light-blue, 29 turquoise, 31 white</td>
</tr>
<tr>
<td>11</td>
<td>turquoise × white</td>
<td>all light-blue</td>
</tr>
<tr>
<td>12</td>
<td>white × white</td>
<td>all white</td>
</tr>
<tr>
<td>13</td>
<td>purple × white</td>
<td>all purple</td>
</tr>
</tbody>
</table>

How many genes and alleles are involved in the inheritance of flower color? Indicate all possible genotypes for the following phenotypes: (a) purple; (b) blue; (c) turquoise; (d) light-blue; (e) white.

4.9 A woman who has blood type O and blood type M marries a man who has blood type AB and blood type MN. If we assume that the genes for the A-B-O and M-N blood typing systems assort independently, what blood types might the children of this couple have, and in what proportions?

4.10 A Japanese strain of mice has a peculiar uncoordinated gait called waltzing, which is due to a recessive allele, w. The dominant allele V causes mice to move in a coordinated fashion. A mouse geneticist has recently isolated another recessive mutation that causes uncoordinated movement. This mutation, called tango, could be an allele of the waltzing gene, or it could be a mutation in an entirely different gene. Propose a test to determine whether the waltzing and tango mutations are alleles, and if they are, propose symbols to denote them.

4.11 Congenital deafness in human beings is inherited as a recessive condition. In the pedigree below, two deaf individuals, each presumably homozygous for a recessive mutation, have married and produced four children with normal hearing. Propose an explanation.

4.12 In the fruit fly, recessive mutations in either of two independently assorting genes, brown and purple, prevent the synthesis of red pigment in the eyes. Thus, homozygotes for either of these mutations have brownish-purple eyes. However, heterozygotes for both of these mutations have dark red, that is, wild-type eyes. If such double heterozygotes are intercrossed, what kinds of progeny will be produced, and in what proportions?

4.13 The dominant mutation Plum in the fruit fly also causes brownish-purple eyes. Is it possible to determine by genetic experiments whether Plum is an allele of the brown or purple genes?

4.14 From information given in the chapter, explain why mice with yellow coat color are not true-breeding.

4.15 A couple has four children. Neither the father nor the father nor the mother is bald; one of the two sons is bald, but neither of the daughters is bald. (a) If one of the daughters marries a nonbald man and they have a son, what is the chance that the son will become bald as an adult? (b) If the couple has a daughter, what is the chance that she will become bald as an adult?

4.16 The pedigree below shows the inheritance of ataxia, a rare neurological disorder characterized by uncoordinated movements. Is ataxia caused by a dominant or a recessive allele? Explain.

4.17 Chickens that carry both the alleles for rose comb (R) and pea comb (P) have walnut combs, whereas chickens that lack both of these alleles (that is, they are genotypically rr pp) have single combs. From the information about interactions between these two genes given in the chapter, determine the phenotypes and proportions expected from the following crosses: (a) RR Pp × rr Pp; (b) rr PP × Rr Pp; (c) Rr Pp × Rr pp; (d) Rr pp × rr pp.

4.18 Rose-comb chickens mated with walnut-comb chickens produced 15 walnut, 14 rose, 5 pea, and 6 single-comb chicks. Determine the genotypes of the parents.

4.19 Summer squash plants with the dominant allele C bear white fruit, whereas plants homozygous for the recessive allele c bear colored fruit. When the fruit is colored, the dominant allele G causes it to be yellow; in the absence of this allele (that is, with genotype gg), the fruit color is green. What are the F2 phenotypes and proportions expected from intercrossing the progeny of CC GG and cc gg plants? Assume that the C and G genes assort independently.

4.20 The white Leghorn breed of chickens is homozygous for the dominant allele C, which produces colored feathers. However, this breed is also homozygous for the dominant allele b of an independently assorting gene that inhibits coloration of the feathers. Consequently, Leghorn chickens have white feathers. The white Wyandotte breed of chickens has neither the allele for color nor the inhibitor of color; it is therefore genotypically cb. What are the F2 phenotypes and proportions expected from intercrossing the progeny of a white Leghorn hen and a white Wyandotte rooster?

4.21 Fruit flies homozygous for the recessive mutation scarlet have bright red eyes because they cannot synthesize brown pigment. Fruit flies homozygous for the recessive mutation brown have brownish-purple eyes because they cannot synthesize red pigment.
4.22 Consider the following hypothetical scheme of determination of coat color in a mammal. Gene \( A \) controls the conversion of a white pigment \( P_0 \) into a gray pigment \( P_1 \); the dominant allele \( A \) produces the enzyme necessary for this conversion, and the recessive allele \( a \) produces an enzyme without biochemical activity. Gene \( B \) controls the conversion of the gray pigment \( P_1 \) into a black pigment \( P_2 \); the dominant allele \( B \) produces the active enzyme for this conversion, and the recessive allele \( b \) produces an enzyme without activity. The dominant allele \( C \) of a third gene produces a polypeptide that completely inhibits the activity of the enzyme produced by gene \( A \); that is, it prevents the reaction \( P_0 \rightarrow P_1 \). Allele \( c \) of this gene produces a defective polypeptide that does not inhibit the reaction \( P_0 \rightarrow P_1 \). Genes \( A, B, \) and \( C \) assort independently, and no other genes are involved. In the \( F_2 \) of the cross \( AA bb CC \times aa BB cc \), what is the expected phenotypic segregation ratio?

4.23 What \( F_2 \) phenotypic segregation ratio would be expected for the cross described in the preceding problem if the dominant allele, \( C \), of the third gene produced a product that completely inhibited the activity of the enzyme produced by gene \( B \)—that is, prevented the reaction \( P_1 \rightarrow P_2 \), rather than inhibiting the activity of the enzyme produced by gene \( A \)?

4.24 The Micronesian Kingfisher, *Halcyon cinnamomina*, has a cinnamon-colored face. In some birds, the color continues onto the chest, producing one of three patterns: a circle, a shield, or a triangle; in other birds, there is no color on the chest. A male with a colored triangle was crossed with a female that had no color on her chest, and all their offspring had a colored shield on the chest. When these offspring were intercrossed, they produced an \( F_2 \) with a phenotypic ratio of 3 circle: 6 shield: 3 triangle: 4 no color. (a) Determine the mode of inheritance for this trait and indicate the genotypes of the birds in all three generations. (b) If a male without color on his chest is mated to a female with a colored shield on her chest and the \( F_1 \) segregate in the ratio of 1 circle: 2 shield: 1 triangle, what are the genotypes of the parents and their progeny?

4.25 In a species of tree, seed color is determined by four independently assorting genes: \( A, B, C, \) and \( D \). The recessive alleles of each of these genes (\( a, b, c, \) and \( d \)) produce abnormal enzymes that cannot catalyze a reaction in the biosynthetic pathway for seed pigment. This pathway is diagrammed as follows:

White precursor \( \rightarrow \) Yellow \( \rightarrow \) Orange \( \rightarrow \) Red

When both red and blue pigments are present, the seeds are purple. Trees with the genotypes \( Aa Bb Cc Dd \) and \( Aa Bb Cc dd \) were crossed. (a) What color are the seeds in these two parental genotypes? (b) What proportion of the offspring from the cross will have white seeds? (c) Determine the relative proportions of red, white, and blue offspring from the cross.

4.26 Multiple crosses were made between true-breeding lines of black and yellow Labrador retrievers. All the \( F_1 \) progeny were black. When these progeny were intercrossed, they produced an \( F_2 \) consisting of 91 black, 39 yellow and 30 chocolate. (a) Propose an explanation for the inheritance of coat color in Labrador retrievers. (b) Propose a biochemical pathway for coat color determination and indicate how the relevant genes control coat coloration.

4.27 Two plants with white flowers, each from true-breeding strains, were crossed. All the \( F_1 \) plants had red flowers. When these \( F_1 \) plants were intercrossed, they produced an \( F_2 \) consisting of 177 plants with red flowers and 142 with white flowers. (a) Propose an explanation for the inheritance of flower color in this plant species. (b) Propose a biochemical pathway for flower pigmentation and indicate which genes control which steps in this pathway.

4.28 Consider the following genetically controlled biosynthetic pathway for pigments in the flowers of a hypothetical plant:

\[
\begin{align*}
P_0 & \rightarrow \text{enzyme A} \rightarrow P_1 \\
P_1 & \rightarrow \text{enzyme B} \rightarrow P_2 \\
P_2 & \rightarrow \text{enzyme C} \rightarrow P_3
\end{align*}
\]

Assume that gene \( A \) controls the conversion of a white pigment, \( P_0 \), into another white pigment, \( P_1 \); the dominant allele \( A \) specifies an enzyme necessary for this conversion, and the recessive allele \( a \) specifies a defective enzyme without biochemical function. Gene \( B \) controls the conversion of the white pigment, \( P_1 \), into a pink pigment, \( P_2 \); the dominant allele, \( B \), produces the enzyme necessary for this conversion, and the recessive allele, \( b \), produces a defective enzyme. The dominant allele, \( C \), of the third gene specifies an enzyme that converts the pink pigment, \( P_2 \), into a red pigment, \( P_3 \); its recessive allele, \( c \), produces an altered enzyme that cannot carry out this conversion. The dominant allele, \( D \), of a fourth gene produces a polypeptide that completely inhibits the function of enzyme \( C \); that is, it blocks the reaction \( P_2 \rightarrow P_3 \). Its recessive allele, \( d \), produces a defective polypeptide that does not block this reaction. Assume that flower color is determined solely by these four genes and that they assort independently. In the \( F_2 \) of a cross between plants of the genotype \( AA bb CC DD \) and plants of the genotype \( aa BB cc dd \), what proportion of the plants will have (a) red flowers? (b) pink flowers? (c) white flowers?
*12. A mouse with the wild-type phenotype:

(a) must be homozygous for recessive alleles at every locus
(b) must be homozygous for dominant alleles at every locus
(c) must have a dominant allele at each locus, but does not have to be homozygous
(d) may be heterozygous at every locus and still be wild-type
(e) none of the above

*13. You have obtained a series of mutants, all affecting the same phenotype, e.g., coat color. Each mutant, when crossed to a wild-type, genetically behaves as a single gene recessive mutation. Explain how you might determine whether these mutations are of the same gene or of more than one gene.

*14. In British cattle there are those phenotypes with normal long legs called Kerry and others with extremely shortened legs called Dexter. The Kerry cattle, when crossed to each other, produce only progeny with the Kerry phenotype. Dexter cattle, when crossed with Kerry cattle, produce the Kerry and Dexter phenotypes in a 1:1 ratio. It is not possible to obtain true breeding strains of the Dexter phenotype. When Dexter are crossed with Dexter, about 1/4 of the calves are the Kerry phenotype, 1/2 are the Dexter phenotype, and 1/4 are spontaneously aborted after about seven months of gestation. These calves are born dead and have extremely shortened legs and nose. Their superficial resemblance to a bulldog led to the name of bulldog calves. Interpret the genetics of the Kerry and Dexter phenotypes.

*15. An insect from a strain breeding true for white eyes was crossed to an insect from a strain breeding true for red eyes. The F₁'s all had red eyes. The F₁'s were crossed to produce an F₂ generation that consisted of 175 red-eyed: 62 cream-eyed: 81 white-eyed.

(a) The results illustrate the phenomenon of ______________________

(b) Provide genotypes for the parents, F₁'s and F₂'s of this cross.

(c) Illustrate a biochemical pathway that best explains the steps in pigment production, and indicate the step affected by each gene.

*16. Now assume when you crossed the red-eyed and white-eyed insects that the F₁'s all had white eyes, and the F₂'s consisted of 243 white-eyed: 58 red-eyed: 21 cream-eyed individuals.

(a) The results illustrate the phenomenon of ______________________

(b) Provide genotypes for the parents, F₁'s and F₂'s of this cross.
(c) Illustrate a biochemical pathway that best explains the steps in pigment production, and indicate the step affected by each gene.

17. In a particular species of fish, a region proximal on the tail may be unspotted or possess one spot, two spots, three spots, or a crescent marking. The following table lists a series of fish crosses and their offspring in regard to tail markings.

<table>
<thead>
<tr>
<th>No. of Cross</th>
<th>Parents</th>
<th>Offspring</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>one-spot X one-spot</td>
<td>95 one-spot</td>
</tr>
<tr>
<td>B</td>
<td>crescent X crescent</td>
<td>101 crescent</td>
</tr>
<tr>
<td>C</td>
<td>unspotted X unspotted</td>
<td>98 unspotted</td>
</tr>
<tr>
<td>D</td>
<td>one-spot X one-spot</td>
<td>74 one-spot, 26 unspotted</td>
</tr>
<tr>
<td>E</td>
<td>crescent X crescent</td>
<td>69 crescent, 22 unspotted</td>
</tr>
<tr>
<td>F</td>
<td>crescent X one-spot</td>
<td>49 crescent, 23 one-spot, 27 unspotted</td>
</tr>
<tr>
<td>G</td>
<td>crescent X two-spot</td>
<td>50 crescent, 24 two-spot, 25 unspotted</td>
</tr>
<tr>
<td>H</td>
<td>two-spot X one-spot</td>
<td>98 three-spot</td>
</tr>
<tr>
<td>I</td>
<td>three-spot X three-spot</td>
<td>55 three-spot, 27 one-spot, 28 two-spot</td>
</tr>
</tbody>
</table>

Analyze these data and indicate all possible genotypes for the following phenotypes (use logical allelic symbols of your choice).

- unspotted
- one-spotted
- two-spotted
- three-spotted
- crescent
18. A geneticist crossed two true-breeding lines of a pet bird. One line "chirped" and had maroon feathers. The other line "screeched" and had brown feathers. All the F₁s had maroon feathers and chirped. The F₂s were crossed and the F₃ data were distributed in the following ratio.

- 27/64 maroon feathers, chirper
- 12/64 brown feathers, chirper
- 9/64 maroon feathers, screecher
- 9/64 red feathers, chirper
- 4/64 brown feathers, screecher
- 3/64 red feathers, screecher

Provide a legend for the above inheritance and indicate the specific type of gene interaction (if any) that occurs in this cross.

19. In wild sunflowers, populations occur that have yellow flowers with black centers (wild-type), and yellow flowers with yellow centers. The following summarizes a series of crosses involving true breeding sunflower plants:

Cross #1  
P wild-type X yellow-centered (plant 1)  
F₁ black-centered  
F₂ 75 black-centered, 26 yellow-centered

Cross #2  
P wild-type X yellow-centered (plant 2)  
F₁ black-centered  
F₂ 62 black-centered, 21 yellow-centered

Cross #3  
P yellow-centered (plant 1) X yellow-centered (plant 2)  
F₁ black-centered  
F₂ 56 black-centered, 44 yellow-centered

(a) Using genetic symbols of your choice, provide a legend for the inheritance of color of flower centers in the sunflower.

(b) What specific kind of interaction is apparent from the results?
4.12 9/16 dark red, 7/16 brownish-purple

4.13 No. The test for allelism cannot be performed with dominant mutations.

4.14 The allele for yellow fur is homozygous lethal.

4.15 The mother is Bb and the father is bb. The chance that a daughter is Bb is 1/2. (a) The chance that the daughter will have a bald son is (1/2) x (1/2) = 1/4. (b) The chance that the daughter will have a bald daughter is zero.

4.16 Dominant. The condition appears in every generation and nearly every affected individual has an affected parent. The exception, IV-2, had a father who carried the ataxia allele but did not manifest the trait—an example of incomplete penetrance.

4.17 (a) 3/4 walnut, 1/4 rose; (b) 1/2 walnut, 1/2 pea; (c) 3/8 walnut, 3/8 rose, 1/8 pea, 1/8 single; (d) 1/2 rose, 1/2 single.

4.18 Rr pp x Rr Pp

4.19 12/16 white, 3/16 yellow, 1/16 green.

4.20 13/16 white, 3/16 colored

4.21 9/16 dark red (wild-type), 3/16 brownish-purple, 3/16 bright red, 1/16 white.

4.22 9 black: 3 gray: 52 white

4.23 9 black: 39 gray: 16 white.

4.24 (a) The simplest explanation for the inheritance of the trait is recessive epistasis combined with incomplete dominance, summarized in the following table:

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Phenotype</th>
<th>Frequency in F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA B-</td>
<td>round</td>
<td>3/16</td>
</tr>
<tr>
<td>Aa B-</td>
<td>shield</td>
<td>6/16</td>
</tr>
<tr>
<td>aa B-</td>
<td>triangular</td>
<td>3/16</td>
</tr>
<tr>
<td>A- bb</td>
<td>no color</td>
<td>3/16</td>
</tr>
<tr>
<td>aa bb</td>
<td>no color</td>
<td>1/16</td>
</tr>
</tbody>
</table>

The cross was triangular aa BB male x no color AA bb female --> shield Aa Bb F1 --> F2 shown in the table. (b) The male without a colored patch must be either A- bb or aa bb; the female with the shield must be As BB or As Bb. Because none of the offspring lack a colored patch, the female's genotype is As BB, and the male's is As bb. Thus, shield male (As BB) x no color female (As bb) --> 1/4 round (AA Bb), 1/2 shield (As Bb), and 1/4 triangular (aa Bb).

4.25 (a) purple X red; (b) proportion white (aa) = 1/4; (c) proportion red (A- B- C- Dd) = (3/4)(3/4)(3/4)(1/2) = 27/128, proportion white (aa) = 1/4 = 32/128, proportion blue (A- B- cc Dd) = (3/4)(3/4)(1/4)(1/2) = 9/128.

4.26 (a) Because the F2 segregation is approximately 9 black: 3 chocolate: 4 yellow, coat color is determined by epistasis between two independently assorting genes: black = B- E-; chocolate = bb E-; yellow = B- ee or bb ee. (b) yellow pigment --E--> brown pigment--B--> black pigment.

4.27 (a) Because the F2 segregation is approximately 9 red: 7 white, flower color is due to epistasis between two independently assorting genes: red = A- B- and white = aa B- , A-bb, or aa bb. (b) colorless precursor--A--> colorless product--B--> red pigment.

4.28 (a) proportion red = (3/4)³ x (1/4) = 27/256; (b) proportion pink = (3/4)⁴ + [(3/4)² x (1/4)] = 117/256; (c) proportion white = 1 - 144/256 = 112/256
APPROACHES TO PROBLEM SOLVING

11. From the mating, *Aa X Aa*, there is a .25 probability of obtaining "aa". The "aa" genotype displays reduced penetrance (.75). Therefore, the probability of obtaining an individual expressing the trait is (.25)(.75) = .1875 or 3/16. The ratio of normal to affected progeny is expected to be 13/16: 3/16 = 13:3.

12. A phenotypically wild-type mouse will be expressing the most common, non-selected phenotype. Some of the wild-type traits will be determined by dominant alleles, others by recessive alleles. Therefore, the answer is (c) none of the above.

13. If all of the recessive mutant alleles are of the same gene, they should yield a mutant phenotype when combined in a hybrid. A dominant hybrid phenotype results from complementation of alleles of different genes. Additional evidence that the mutants are all of the same gene is obtained if only monohybrid ratios are observed in *F₂* progeny of crosses between the mutant individuals. If a dihybrid ratio is observed in the *F₂* generation of a cross, then the parents must have differed at two gene pairs.

14. The cross of Dexter X Kerry gives a 1:1 ratio, suggesting that a heterozygous gene pair is segregating in one parent. Kerry X Kerry crosses always produce Kerry offspring. Dexter X Dexter crosses produce 1/4 Kerry: 1/2 Dexter: 1/4 bulldog calves. This indicates that the Dexter phenotype is heterozygous for the Dexter and Kerry alleles. Dexter is lethal in the homozygous condition resulting in bulldog calves, but acts like a dominant allele in the heterozygous condition.

15. The 175 red, 62 cream, and 81 white progeny in the *F₂* reduces to a 9/16: 3/16: 4/16 ratio. The 16 in the denominator indicates that two gene pairs are segregating in the *F₁*, and therefore, the *F₂* is a dihybrid. The *F₁* can be arbitrarily given the genotype of *AaBb*. The phenotypes of the *F₂* can be interpreted in terms of a modified dihybrid ratio:

- 9 *A_* *B_*
- 3 *A_* *b_*
- 3 *a* *a* *B_*
- 1 *a* *a* *b* *b*

The dominant alleles "A" and "B" interact to produce the red phenotype which is expected to occur in a frequency of 9/16. The white phenotype results from recessive epistasis of "aa", and comprises 4/16 of the progeny. A colored phenotype can occur only if the genotype is *A_* *B*_. The cream allele "b" is a recessive mutant of the red allele "B". The cream phenotype results from the genotype *A_* *b_* which occurs 3/16 of the time.

(a) The results illustrate the phenomenon of recessive epistasis (9:3:4 ratio).

(b) The genotypes for the parents, *F₁*'s and *F₂*'s of this cross are:

- *P* red *(AABB)* X white *(aabb)*
- *F₁* red *(AaBb)*
- *F₂* *A_* *B_* = red
  *A_* *b_* = cream
  *a* *a* *B_* = white
  *a* *a* *b* *b* = white

58 Chapter 4
(c) Illustrate a biochemical pathway that best explains the steps in pigment production, and indicate the step affected by each gene.

Dominant alleles code for enzymes which carry out specific steps in biochemical pathways. Recessive alleles are mutants of the dominant allele that code for a nonfunctional or partially functional enzyme or no enzyme at all. Homozygosity for a recessive allele may result in a block in a biochemical pathway because of production of a nonfunctional enzyme. With these concepts in mind, a biochemical pathway can be illustrated as follows:

\[
\begin{align*}
\text{Gene A} & \quad \text{Gene B} \\
\downarrow & \quad \downarrow \\
\text{colorless} & \quad \text{cream} \\
\text{precursor} & \quad \text{pigment} \\
\text{enzyme A} & \quad \text{enzyme B} \\
& \quad \text{red} \\
& \quad \text{pigment}
\end{align*}
\]

16. The 243 white: 58 red: 21 cream reduces to a 12/16: 3/16: 1/16 ratio or 12: 3: 1. The 16 in the denominator indicates that the \( F_1 \) is segregating for two gene pairs. It follows that the \( F_1 \) can be written as \( Aa Bb \). The \( F_1 \) can be analyzed in respect to a modified 9:3:3:1 dihybrid ratio.

\[
\begin{align*}
9 & \quad A_- B_- \\
3 & \quad A_- b b \\
3 & \quad a a B_- \\
1 & \quad a a b b
\end{align*}
\]

If dominant epistasis is assigned to the white determining "A" allele, then anytime "A" is present the eye color will be white, regardless of the genotype at the second gene pair. The insect must be "aa" for color to be expressed. The allele "B" results in red eye color only if the insect is "aa". The recessive cream eye color phenotype results if the insect is "aa bb".

(a) The results illustrate the phenomenon of dominant epistasis (12:3:1 ratio).

(b) Provide genotypes for the parents, \( F_1 \)'s and \( F_2 \)'s of this cross.

\[
\begin{align*}
\text{P} & \quad \text{red (aa BB) X white (AAbb)} \\
\text{F}_1 & \quad \text{white (Aa Bb)} \\
\text{F}_2 & \quad A_- a_-= \text{white} \\
& \quad a a B_- = \text{red} \\
& \quad a a b b = \text{cream}
\end{align*}
\]

(c) Illustrate a biochemical pathway that best explains the steps in pigment production, and indicate the step affected by each gene.

A hypothetical biochemical pathway can be illustrated by having an enzyme, coded by allele "B", convert a cream colored precursor to the red pigment. Allele "b" does not code for a functional enzyme. In our model, an enzyme coded by allele "A" is much more active than the enzyme coded by allele "B", and when present all of the cream colored pigment is converted to a colorless compound and white eyes result. The alleles at the second gene pair are expressed
only if the insect is "aa" at the first gene pair, assuming that the "a" allele does not code for a functional enzyme.

Gene B

\[ \downarrow \]

enzyme B

\[ \text{cream} \rightarrow \text{red pigment} \]

Gene A \[ \Rightarrow \text{enzyme A} \]

\[ \downarrow \]

colorless compound

17. To approach this problem it is best to first look at the ratios of the crosses. In doing this it is seen that all data can be reduced to 3:1, 1:2:1, or 1:1 ratios, which all result from monohybrid crosses. Therefore, multiple alleles of a single gene are segregating in these crosses.

Crosses A, B, and C indicate that one-spot, crescent, and unspotted can be in the form of homozygous genotypes. This is concluded from the fact that no segregation of phenotypes is seen in these crosses.

Cross D indicates that the one-spot allele (arbitrarily designated as \( t^1 \)) is dominant to the unspotted allele \( t^0 \) since a 3:1 ratio of one-spot to unspotted is observed among the progeny.

Cross E indicates that crescent \( (t^C) \) is dominant to unspotted.

Cross F suggests that the genotype of crescent is \( t^C t^0 \) and the genotype of one-spot is \( t^1 t^0 \).

Since the crescent phenotype makes up 1/2 of the progeny, crescent must be dominant to both the unspotted and one-spot allele and one-spot is dominant to unspotted.

Cross G likewise indicates that the crescent fish is heterozygous for crescent and unspotted, and the two-spot fish is heterozygous for the two-spot and the unspotted alleles.

This cross, \( F^C t^0 \times t^1 t^0 \) produces 1/2 crescent \( \text{t}^C t^2 \) and \( t^C t^0 \), 1/4 two-spot \( \text{t}^0 t^0 \) and 1/4 unspotted \( t^0 t^0 \). The crescent allele is dominant to the two-spot allele. The two-spot allele is dominant to the unspotted allele.

Cross H suggests that three-spot results from the heterozygous condition for two-spot and one-spot.

Cross I confirms that the genotype of three-spot is \( t^1 t^2 \). Three spot \( (t^1 t^2) \times \text{three-spot } (t^1 t^2) \) results in 1/2 three-spot \( (t^2 t^2) \), 1/4 one-spot \( (t^1 t^1) \) and 1/4 two-spot \( (t^1 t^2) \).

All possible genotypes are indicated for the following phenotypes:

- unspotted \( t^0 t^0 \)
- one-spotted \( t^1 t^0, t^1 t^0 \)
- two-spotted \( t^1 t^1, t^2 t^0 \)
- three-spotted \( t^1 t^2 \)
- crescent \( t^C t^0, t^C t^0, t^1, t^1 t^2 \)
18. A superficial glance at the ratios with 64 in the denominator indicates that three gene pairs are segregating in this cross. It is easiest to analyze this cross by breaking it into simpler components. Therefore, first consider the inheritance of chirping and screeching.

\[ \text{P chirper X screecher} \]

\[ \text{F}_1 \text{ chirper} \]

\[ \text{F}_2 \frac{27}{64} + \frac{12}{64} + \frac{9}{64} = \frac{48}{64} \text{ chirpers} \]

\[ \frac{9}{64} + \frac{4}{16} + \frac{3}{64} = \frac{16}{64} \text{ screechers} \]

The 3:1 ratio indicates that chirper is dominant to screecher.

Next, consider the inheritance of maroon, red, and brown.

\[ \text{P maroon feathers X brown feathers} \]

\[ \text{F}_1 \text{ maroon feathers} \]

\[ \text{F}_2 \frac{27}{64} + \frac{9}{64} = \frac{36}{64} \text{ maroon} \]

\[ \frac{9}{64} + \frac{3}{64} = \frac{12}{64} \text{ red} \]

\[ \frac{12}{64} + \frac{4}{64} = \frac{16}{64} \text{ brown} \]

The 36:12:16 or 9:3:4 ratio indicates that two genes are involved in inheritance of feather color and also that recessive epistasis occurs for the brown allele.

The legend is:

<table>
<thead>
<tr>
<th>Chirper</th>
<th>Maroon</th>
<th>Red</th>
<th>Brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>R</td>
<td>r</td>
<td>b</td>
</tr>
</tbody>
</table>

Crosses #1 and #2 indicate that the two yellow-center strains differ from the wild-type (black center) at one gene pair. Black is dominant to yellow as deduced from the 3:1 ratio in each cross. Further analysis indicates that the yellow-center alleles of cross #1 and cross #2 are of two different gene pairs because they complement each other to give the wild-type in the F$_1$ hybrid. The dihybrid nature of this cross is seen when the F$_2$ data of 56 black-centered to 44 yellow-centered are reduced to a 9/16 to 7/16 ratio. This is a duplicate recessive epistatic ratio. Therefore, the yellow-centered alleles of each gene pair display recessive epistasis. The legend for this inheritance is:

\[ B_\_ C_\_ = \text{black center} \]

\[ -- C C_\_ = \text{yellow center} \]

\[ B B_\_ = \text{yellow center} \]