Solutions Manual for

AN INTRODUCTION TO GENETIC ANALYSIS

SECOND EDITION

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CONTENTS

Chapter 2

1. Charlie was not pure breeding but heterozygous, Bb, where b is a recessive allele causing a red and white coat. His mates were BB. Half of his progeny were Bb, and these, when interbred, gave 3 B-:1 bb.

2. Recessive.

3. There are several approaches, of which the following is probably the most universal in its applicability since it circumvents possible problems due to self incompatibility (inability to self). Take the anthers of the white flower and look for an unopened (hence unpollinated) blue flower. Open it, carefully remove its anthers without bursting them, and apply pollen from the white flower's anthers onto the stigma. Cover the flower with a gauze bag to prevent insect visits, mark the plant, and return once seeds have appeared. If all progeny grow up white, then white is dominant; if all progeny are blue, then blue is dominant. But if 1/2 are blue and 1/2 are white then either allele could be dominant. In this case, intercross two of these progeny blues. If some whites are produced, blue is dominant; if no whites produced, blue must be recessive. As a failsafe, mark the white plant in order to collect seeds from it later. One generation is lost using this method, but it does guarantee that the albino allele is not lost.

4. If tasting were recessive, Mom and Dad would have to be homozygous and then all their children would taste too. Since some children do not taste, tasting must be dominant, Mom and Dad must be heterozygous, and nontasting must be recessive.

5. The woman must be heterozygous Gg. The man had one parent who must have been Gg, so there is a 1/2 chance that he is Gg too. Thus, the probability of them both being Gg is 1 x 1/2 = 1/2, and the probability of an affected offspring is 1/2 x 1/4 = 1/8.

6. The father is probably Hh (disease is rare), so the man has a 1/2 chance of getting H from his father.

   a. 1/2
   b. 1/2 x 1/2 = 1/4

7. a. Dominant
   b. Dd and Dd
   c. 1/4 for normal, 3/4 for dwarf

8. Prob(both normal pigment) = 3/4 x 3/4 = 9/16
   Prob(both albino) = 1/4 x 1/4 = 1/16
   Prob(both look the same) = 10/16 = 5/8

9. 91 spotted-leafed plants and 28 unspotted, approximately a 3:1 ratio.
   a. Spots = S, no spots = s. Parental plant Ss gave 3/4 S- and 1/4 ss.
   b. All unspotted plants should be pure breeding, and 1/3 of spotted plants should be pure breeding.

10. a. The third cross indicates that thrum is dominant to pin. Therefore, the pin plants must be homozygous, hh. The second cross shows that thrum plant 3 is homozygous, HH. The last cross indicates that thrum plant 4 is heterozygous, Hh.
    b. (1) all thrum, (2) all thrum, (3) 3 thrum:1 pin

11. While it cannot be proven, evidence can be assembled to suggest that the probability that the animal is heterozygous is small. Each of the progeny of a cross of Aa x aa has a 1/2 chance of being aa. Therefore, if an animal with the phenotype A- is crossed with an aa individual and yields n progeny, all with the A- phenotype, then the probability that the A- individual is Aa is equal to $1/(2^n)$.

12. A mutation may have occurred. It is also possible that seed color is determined by maternal genotype (cf. Chapter 15) or that yellow is dominant but incompletely penetrant (cf. Chapter 4).

13. These data suggest that fruit shape is determined by a single pair of alleles, with winged dominant to wingless. The odd individuals occur at too great a rate to be attributed to mutation. They probably result from counting errors, accidental contamination, or mixing.

14. Pedigree 1: Must be recessive--key is presence of trait in a child whose parents were both normal. Genotypes:
    Row 1: A-, aa
    Row 2: Aa, Aa, Aa, A-, A-, Aa.
    Row 3: Aa, Aa
    Row 4: aa

    Pedigree 2: Must be dominant--key is absence of trait in a child whose parents were both abnormal. Genotypes (of abnormal individuals only, normals are all aa):
    Row 1: Aa, Aa
    Row 2: Aa, Aa, Aa, Aa
    Row 3: A-, A-, A-, Aa

    Pedigree 3: Could be dominant or recessive. However, recessiveness is unlikely, since that hypothesis requires that all phenotypically normal individuals who marry into the family are heterozygous carriers.

Genotypes (assuming dominance):
Original abnormal individual is A-; all other abnormals are Aa; all normals are aa.

Pedigree 4: Must be recessive--key is presence of trait in children of two normal individuals.
Genotypes:
Row 1: aa, A-, Aa, Aa
Row 2: Aa, Aa, Aa, aa, A-, aa, A-, A-, A-, A-, A-
Row 3: Aa, aa, Aa, Aa, aa, Aa

15. 1/4

16. 1/32

17. This problem may at first seem a bit difficult, but a quick analysis shows that it is not. For an F_2 individual to receive half its alleles from one grandparent and half from the other, it must be AaBb, AAbb or aaBB. To receive all of its alleles from one grandparent, it must be either AABB or aabb. Knowing that the F_1 individual is AaBb, we can calculate the needed probabilities: prob(AaBb) = 1/2 x 1/2 = 1/4; prob(AAbb) = 1/4 x 1/4 = 1/8; prob(aaBB) =1/4 x 1/4 = 1/8. Therefore, the probability that the progeny got half its alleles from each grandparent = 1/4 + 1/8 + 1/8 = 1/2. Similarly, prob(AABB) = 1/4 x 1/4 = 1/8, and prob(aabb) = 1/4 x 1/4 = 1/8. Thus, the probability that all alleles came from one grandparent (or the other) = 1/8 + 1/8 = 1/4.

18. a. CcSs x CcSs
b. CCSs x CCss
c. CcSS x ccSS
d. ccSs x ccSs
e. Ccss x Ccss
f. CCSs x CCSs
g. CcSs x Ccss

19. a. Purple (P) and cut (C) are dominant.
b. 1. PpCc x ppCc
2. PpCc x Ppcc
3. PPCc x ppCc
4. PpCC x ppcc
5. Ppcc x ppCc

20. a. 2
b. Bow and knock are alleles of one; hairy and smooth are alleles of the other.
c. B = bow, b = knock
H = hairy, h = smooth
d. BbHh, BbHH, Bbhh bbhh, BBHh
(p) (q) (r) (s) (t)

So that 1. is $\underline{p}$ x $\underline{q}$ or $\underline{q}$ x $\underline{p}$
2. is $\underline{r}$ x $\underline{s}$
3. is $\underline{p}$ x $\underline{s}$
4. is $\underline{p}$ x $\underline{t}$ or $\underline{t}$ x $\underline{p}$

21. a. $\underline{y^{o}y^{o}}$ $\underline{f^{+}f^{+}}$
$\underline{y^{+}y^{o}}$ $\underline{f^{o}f^{o}}$
$\underline{y^{+}y^{+}}$ $\underline{f^{o}f^{o}}$

b. 0 3/4
0 1/4
c. 9/16 3/16
3/16 1/16
d. A difference of only 1 allele separates them.

22. Phenotypically
a. 1/2 x 3/4 x 1 x 3/4 x 1/2 = 9/64
b. 1/2 x 3/4 x 1 x 3/4 x 1/2 = 9/64
c. 9/64 + 9/64 = 18/64 = 9/32
d. 1 - 9/32 = 23/32

Genotypically
e. 1/2 x 1/2 x 1/2 x 1/2 x 1/2 = 1/32
f. 1/2 x 1/2 x 1/2 x 1/2 x 1/2 = 1/32
g. 1/32 + 1/32 = 2/32 = 1/16
h. 1 - 1/16 = 15/16

Chapter 3

1. This could be done in a number of ways. The most obvious is $\underline{B}$ = brown, $\underline{B}^+$ = black. However, since both "black" and "brown" begin with the letter "b," we might want to provide more information in the allele symbols, such as $\underline{Br}$ = brown, $\underline{Br}^+$ = black.

2. a. 92 b. 92 c. 46 d. 46 e. 23

3. e. chromosome pairing

4. a. Mitosis preserves the number of chromosomes in the cell. Since the original cell had 10 pairs of chromosomes (i.e., 20 chromosomes), the progeny cells will also have 20.
   b. Meiosis reduces the number of chromosomes by half. Since the original cell had 10 pairs of chromosomes, the progeny cells will have just 10 chromosomes.

5. For a child's karyotype to be the same as his, the man's sperm must contain a satellited 4, an abnormal 7, and a Y. The overall probability of this is 1/2 x 1/2 x 1/2 = 1/8.

6. Probability = 1 x 1/2 x 1/2 x 1/2 ... 1/2 = $(1/2)^{n-1}$.

7. a. You received one member of each homologous pair from your mother. Hence, you have half of your genes in common with her.
   b. This one is not quite so simple. You received half of your genes from your mother and half from your father. Your brother did likewise. Since the genes you received from your mother represent a random sample of 50% of $\underline{her}$ genes, there is a 50% chance that you will share any given one of these with your brother. In other words, there is a 1/4 chance that you share a gene with your brother because you both received it from your mother. Likewise, there is a 1/4 chance that you share a gene with your brother because you both received it from your father. Thus, finally, there is a 1/2 (from 1/4 + 1/4) probability that for any one of your genes, your brother carries an exact match. Another way of saying this is, on the average, brothers share 50% of their genes in common.

8. For the sex ratio to be maintained, the males must produce 50% X-carrying gametes and 50% YY-carrying gametes. In the absence of any other data, any reasonable meiotic arrangement that might yield these results is a good answer.

9. In schmoos, females are obviously the heterogametic sex. Female G x male gg gives Gg male and g female offspring, where G = graceful, g = gruesome.

10. X-linked dominant.

11. If we let H = the allele for hypophosphatemia, then the cross is $X^{h}X^{h}$ by $X^{H}Y$. Thus, only two kinds of progeny can be produced: $X^{H}X^{h}$, which will be hypophosphatemic girls, and $X^{h}Y$, which will be normal boys.

12. The gene could not be on the X chromosome. The simplest explanation would be to suppose it is on the Y chromosome. A less satisfying possiblity would be an autosomal dominant that is expressed only in males and happened to have been inherited by all males in the line.

13. a. Her mother must have been Dd, so there is a 1/2 chance that the woman got the d from her mother and is heterozygous herself. Half of her children will be sons, and 1/2 of them will have muscular dystrophy.
Overall probability = 1/2 x 1/2 x 1/2 = 1/8.

    b. One of the grandparents had the gene, so there is a 1/2 chance that your mother has it, and a further 1/2 chance that you have it, if you are a male or a female.
Overall probability = 1/2 x 1/2 = 1/4.

    c. Since your father does not have the disease, you cannot get it. That is, the probability = 0.

14. a. It must be recessive, since no parents show it. Neither male parental X chromosome carries it, since both fathers are normal. It could be autosomal recessive, but that would require all three parents to be carriers of the same rare allele. It could also be an X-linked recessive, since only male progeny show it. Since this requires that only the mother be a heterozygous carrier, for reasons of simplicity, this is the preferred hypothesis. You should recognize, though, that this pedigree doesn't prove that it's X linked. It just makes it plausible that it's X linked.

    b. Let A be the normal allele, a be the abnormal allele, and Y be the Y chromosome. Then the genotypes are:
Parents: AY, Aa, AY
Progeny: AY, A-, aY, A-, AY, aY, aY, A-, aY, A-

15. a. $X^{\underline{C}}X^{\underline{C}}$ and $X^{\underline{c}}X^{\underline{c}}$
    b. 0.5 x 0.5 = 0.25
    c. 50%
    d. 50%

16. a. Suppose the genes for black and yellow are alleles on the X chromosome, called $\underline{t}^{\underline{b}}$ and $\underline{t}^{\underline{y}}$, respectively. Then males are $X^{\underline{t}^{\underline{b}}}Y$ (black) and $X^{\underline{t}^{\underline{y}}}Y$ (yellow). Females could be $X^{\underline{t}^{\underline{b}}}X^{\underline{t}^{\underline{b}}}$ (black), or $X^{\underline{t}^{\underline{y}}}X^{\underline{t}^{\underline{y}}}$ (yellow), or $X^{\underline{t}^{\underline{b}}}X^{\underline{t}^{\underline{y}}}$ (tortoise-shell).

b.

	Female	Male
P	$X^{\underline{t}^{\underline{y}}}X^{\underline{t}^{\underline{y}}}$ (yellow)	$X^{\underline{t}^{\underline{b}}}Y$ (black)
F_1	$X^{\underline{t}^{\underline{y}}}X^{\underline{t}^{\underline{b}}}$ (tortoise-shell)	$X^{\underline{t}^{\underline{y}}}Y$ (yellow)

c.

	Female	Male
P	$X^{\underline{t}^{\underline{b}}}X^{\underline{t}^{\underline{b}}}$ (black)	$X^{\underline{t}^{\underline{y}}}Y$ (yellow)
F_1	$X^{\underline{t}^{\underline{b}}}X^{\underline{t}^{\underline{y}}}$ (tortoise-shell)	$X^{\underline{t}^{\underline{b}}}Y$ (black)

    d. Tortoise-shell females and black males
    e. Tortoise-shell females and yellow males

17. 1/4

18. These data indicate that the disease is produced by an X-linked recessive.

19. For now, some advantages might be:
    (i) to permit orderly distribution of genes at mitotic and meiotic cell divisions.
    (ii) to maintain favorable gene combinations together.
    (iii) to permit coordinate control of gene function.

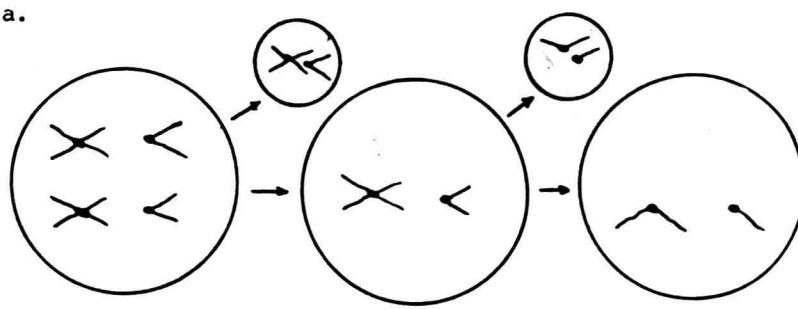
20. a. Excluded
    b. Consistent
    c. Excluded
    d. Excluded
    e. Excluded

21. a. Bent is dominant (bent x bent gives normals in 6).
    b. X linked
    c.

(1)	$\underline{bb} \times \underline{B}$	$\underline{Bb}$	$\underline{b}$
(2)	$\underline{Bb} \times \underline{b}$	1/2 $\underline{Bb}$, 1/2 $\underline{bb}$	1/2 $\underline{B}$, 1/2 $\underline{b}$
(3)	$\underline{BB} \times \underline{b}$	$\underline{Bb}$	$\underline{B}$
(4)	$\underline{bb} \times \underline{b}$	$\underline{bb}$	$\underline{b}$
(5)	$\underline{BB} \times \underline{B}$	$\underline{BB}$	$\underline{B}$
(6)	$\underline{Bb} \times \underline{B}$	1/2 $\underline{BB}$, 1/2 $\underline{Bb}$	1/2 $\underline{B}$, 1/2 $\underline{b}$

22. a. Autosomal, dominant
    b. Most likely sex-linked recessive, but could be autosomal recessive
    c. Assume the eye disease is caused by a sex-linked recessive, and let it be $\underline{e}$. Let the allele for the extra finger be $\underline{F}$.
    $\underline{Ee}$ $\underline{ff}$ female x $\underline{EY}$ $\underline{Ff}$ male
    d. 0 and 0
    e. 0 and 1/8 (assuming her husband is normal)

23. a.



    b. The statement is false. The total <u>population</u> of egg cells produced will not be affected by this discarding of some of the products of meiosis.

Chapter 4

1. The cross is Pp x pp. Therefore, the progeny should be 1 Pp to 1 pp, or 1 pink to 1 white.

2. Erminette is a case of codominance. The phenotype is a heterozygote (Ee), where EE = black, and ee = white. Thus, Ee selfed gives a 1:2:1 ratio. One possible test is to cross erminettes to white; a ratio of 1/2 erminette to 1/2 white is expected.

3. In doing this problem, you must recognize that in mosses the gametophyte is haploid and the sporophyte is diploid. Then you can see that the sporophyte produced must be heterozygous for the two alleles P1 and P2 and thus will produce both electrophoretic forms. Then this diploid sporophyte will undergo meiosis, yielding haploid spores that are carrying either the P1 allele or the P2 allele. Since the haploid gametophytes arise mitotically from these spores, half the progeny gametophytes will show form P1 and the other half will show form P2.

4. a. 1/4 fully fertile
   b. 1/4 fully sterile
   c. 1/2 partially fertile

5. The cross S1S2 x S3S4 will yield the following progeny in equal proportions: S1S3, S1S4, S2S3, S2S4. These can be combined in 10 genetically distinct matings. These matings, and their results, are:

Mating	Compatible	Progeny
S1S3 x S1S3	no	
S1S3 x S1S4	no	
S1S3 x S2S3	yes	S1S2, S1S3, S3S2, S3S3
S1S3 x S2S4	yes	S1S2, S1S4, S3S2, S3S4
S1S4 x S1S4	no	
S1S4 x S2S3	yes	S1S2, S1S3, S4S2, S4S3
S1S4 x S2S4	yes	S1S2, S1S4, S4S2, S4S4
S2S3 x S2S3	no	
S2S3 x S2S4	no	
S2S4 x S2S4	no	

6. None will be Himalayan.

7. a. The protein governing the deposition of pigment into the hair might only function at temperatures lower than core body temperature.
   b. The patch will grow back with fur the same color as on the "points" (the extremities); thus, it will grow back black.

8. Baby 1 is from cross 4, baby 2 is from cross 2, baby 3 is from cross 1, and baby 4 is from cross 3.

9. Child 1 must be husband's (and wife must be $\underline{I^A}\underline{i}$) because lover can't have an O child.
   Child 2 must be lover's as M x N only produces MN children.
   Child 3 could be either husband's or lover's.

10. Platinum phenotype due to an allele that is lethal when homozygous. Test by crossing platinum to normal; predict a 1:1 ratio. Or examine aborted fetuses in platinum x platinum; expect 1/4.

11. a. Simple dominant; rabbits showing the anomaly were heterozygous.
    b. Homozygous dominant. Perhaps most of the homozygotes were so abnormal that they died before birth.
    c. Litter size in the mating described should be about 1/4 smaller than normal; if any of the surviving extreme abnormals can be mated with normals, all offspring should look and breed like heterozygotes; all ordinary Pelger-anomaly rabbits should breed as heterozygotes in all possible types of matings. You could also examine aborted fetuses <u>in utero</u>.
    d. Marriages that might produce homozygotes must be rare. Also, by analogy, homozygous type might die as embryo, or be extremely abnormal and die as baby. (Note: A report of a 2 1/2-year-old girl apparently homozygous for this anomaly indicates that the possibility suggested by this answer is not in fact realized. Begemann et al., <u>Acta Haematol</u>. 7:295, 1952.)
    e. Expected, but subject to chance deviations in any given family; 1 normal:2 Pelger anomaly:1 dead embryo or extremely abnormal baby.

12. Short-bristled flies are always females. Only half as many males are produced as females. Suppose the allele for short bristles is dominant (call it $\underline{S}$). Hence $\underline{S}/\underline{S}^+$ females have short bristles but $\underline{S}$ is also a recessive lethal so that $\underline{S}Y$ males never live. The first cross is:

P	$\underline{S}\underline{S}^+$	x	$\underline{S}^+Y$
F_1	1 $\underline{S}\underline{S}^+$		short-bristled female
	1 $\underline{S}^+\underline{S}^+$		long-bristled female
	1 $\underline{S}^+Y$		long-bristled male
	1 $\underline{S}Y$		dies

The second cross is:

P	$\underline{S^+S^+}$	x	$\underline{S^+Y}$
F	1 $\underline{S^+S^+}$		long-bristled female
	1 $\underline{S^+Y}$		long-bristled male

The third cross is the same as the first.

13. a. Cross must be $\underline{Hh\ Ss}$ x $\underline{Hh\ Ss}$

2/3 $\underline{Hh}$ < 2/3 $\underline{Ss}$ = 4/9 hairy; 1/3 $\underline{ss}$ = 2/9 hairless

1/3 $\underline{hh}$ < 2/3 $\underline{Ss}$ = 2/9 hairy; 1/3 $\underline{ss}$ = 1/9 hairy

Total hairy = 7/9; hairless = 2/9 Ans. = 7:2

b. $\underline{Hh\ ss}$ x $\underline{Hh\ Ss}$

2/3 $\underline{Hh}$ < 1/2 $\underline{Ss}$ = 2/6 hairy; 1/2 $\underline{ss}$ = 2/6 hairless

1/3 $\underline{hh}$ < 1/2 $\underline{Ss}$ = 1/6 hairy; 1/2 $\underline{ss}$ = 1/6 hairy

Total hairy = 4/6; hairless = 2/6 Ans. = 2:1

14. $\underline{P}$ = pink; $\underline{p}$ = blue. $\underline{S}$ = solid; $\underline{s}$ = spotted. Dominance relations obvious by fact that solid pink x solid pink produces some spotted and some blue. $\underline{P}$ must be homozygous lethal, as shown by 2:1 ratio of pink:blue.

Thus, the genotypes of original strains were $\underline{Pp\ ss}$ x $\underline{pp\ SS}$, so that the immediate progeny were 1/2 $\underline{Pp\ Ss}$ (solid pink) and 1/2 $\underline{pp\ Ss}$ (solid blue). You can generate the genotypes of subsequent progeny by following crosses with Punnett squares.

15. The 9:3:3:1 ratio in the F_2 suggests that the F_1 was heterozygous at two loci. This in turn suggests that the fruit color and fruit shape are each governed by a pair of alleles. The fact that the F_1 was all white, disk suggests that white is dominant to yellow and that disk is dominant to sphere. Thus, the cross seems to be:

P:	$\underline{WWDD}$	x	$\underline{wwdd}$
F_1:		$\underline{WwDd}$	
F_2:	9	$\underline{W\text{-}D\text{-}}$	
	3	$\underline{W\text{-}dd}$	
	3	$\underline{wwD\text{-}}$	
	1	$\underline{wwdd}$	

16. Recessive albino alleles at two independent genes. Cross is $\underline{A_1A_1a_2a_2}$ x $\underline{a_1a_1A_2A_2}$; which gives all $\underline{A_1a_1A_2a_2}$ (normal).

17. c^{sr} = sun red, c^{o} = orange, c^{p} = pink, allelic series with dominance in the order shown.

1. $c^{sr}c^{sr}$ x $c^{p}c^{p}$, gives F_1 $c^{sr}c^{p}$, gives 3:1 in F_2

2. $c^{o}c^{o}$ x $c^{sr}c^{sr}$, gives F_1 $c^{o}c^{sr}$, gives 3:1 in F_2

3. $c^{o}c^{o}$ x $c^{p}c^{p}$, gives F_1 $c^{o}c^{p}$, gives 3:1 in F_2

Scarlet is an allele of an independent gene s.

4. $c^{o}c^{o}ss$ x CCss

F_1 $Cc^{o}Ss$, normal (yellow)

F_2 C-S-, yellow 9
C-ss, scarlet 3
$c^{o}c^{o}S-$, orange 3
$c^{o}c^{o}ss$, orange 1 (epistasis)

18. a.

Phenotypes	agouti	x	nonagouti	
Genotypes	AA		aa	
Germ cells	A		a	
F_1 Phenotype	agouti			
Genotype	Aa			
Germ cells	A, a			
F_2 Phenotype	3 agouti:1 nonagouti			
Genotype	1 AA:2 Aa:1 aa			

b.

P	wild-type	x	cinnamon
	BB		bb
Germ cells	B		b
F_1	wild-type		
	Bb		
F_2	3 wild-type:1 cinnamon		
	1 BB:2 Bb:1 bb		

c. AAbb (cinnamon (brown agouti)) x aaBB (black (black non-agouti)) ⟶ AaBb (wild-type (black agouti))

d. aabb (nonagouti brown)

e.

P	Phenotype	cinnamon	x	black
	Genotype	AAbb		aaBB
	Germ cells	Ab		aB
F_1	Phenotype	wild-type		
	Genotype	AaBb		
	Germ cells	AB, Ab, aB, ab		

F_2

1 AABB 2 AaBB 2 AABb 4 AaBb		9 wild-type
1 aaBB 2 aaBb		3 black
1 AAbb 2 Aabb		3 cinnamon
1 aabb		1 chocolate

f. AaBb (wild-type) x AAbb (cinnamon)

AB →	Ab →	AABb	2 wild-type
aB →	Ab →	AaBb	
Ab →	Ab →	AAbb	2 cinnamon
ab →	Ab →	Aabb	

AaBb (wild-type) x aaBB (black)

AB →	aB →	AaBB	2 wild-type
Ab →	aB →	AaBb	
aB →	aB →	aaBB	2 black
ab →	aB →	aaBb	

g. AaBb (wild-type) x aabb (chocolate)

AB →	ab →	AaBb	1 wild-type
Ab →	ab →	Aabb	1 cinnamon
aB →	ab →	aaBb	1 black
ab →	ab →	aabb	1 chocolate

h. (1) AAbbcc
(2) AABBcc
(3) aaBBcc
(4) aabbcc

19. This kind of problem is best approached by first summarizing everything that is known: gray male (A-R-) x yellow female (A-rr) yields 3/8 yellow (A-rr), 3/8 gray (A-R-), 1/8 black (aaR-), and 1/8 white (aarr). Since 1/8 of the progeny were white (that is, were homozygous for the recessive alleles at both loci) both parents must have been carrying at least one recessive allele at each locus. Therefore, the parental genotypes were AaRr x Aarr.

20. The 9:3:3:1 indicates that 2 pairs of genes are involved. The alleles for scarlet and brown eyes must be recessive since the F_1 are normal. Let the allele for scarlet eyes be s and the allele for brown eyes be b.