E1. Mexican hairless dogs are heterozygous for a dominant allele that is lethal when homozygous. In a cross between two Mexican hairless dogs, we expect 1/4 to be normal, 1/2 to be hairless, and 1/4 to die.

E2. Chinchilla 1 is heterozygous $c^{ch}c$.
Chinchilla 2 is heterozygous $c^{ch}c^h$.
Chinchilla 3 is heterozygous $c^{ch}c$.
Chinchilla 4 is probably $c^{ch}c^{ch}$ because it always produces chinchilla offspring when mated to chinchilla 1 or 2, which are heterozygous. However, it is possible that chinchilla 4 is also heterozygous $c^{ch}c^h$ or $c^{ch}c$.
Chinchilla 5 is $c^{ch}c^h$ or $c^{ch}c$.

As noted, we are not sure about the genotypes of chinchillas 4 and 5.

E3. There may be two redundant genes that are involved in feathering. The unfeathered Buff Rocks are homozygous recessive for the two genes. The Black Langhans are homozygous dominant for both genes. In the F_2 generation (which is a double heterozygote crossed to another double heterozygote), 1 out of 16 offspring will be doubly homozygous for both recessive genes. All the others will have at least one dominant allele for one of the two (redundant) genes.

E4. The first offspring must be homozygous for the horned allele. The father's genotype is still ambiguous; he could be heterozygous or homozygous for the horned allele. The mother's genotype must be heterozygous because her phenotype is polled (she cannot be homozygous for the horned allele) but she produced a horned daughter (who must have inherited a horned allele from its mother).

E5. The reason why all the puppies have black hair is because albino alleles are found in two different genes. If we let the letters *A* and *B* represent the two different pigmentation genes, then one of the dogs is *AAbb* and the other is *aaBB*. Their offspring are *AaBb* and therefore are not albinos because they have one dominant copy of each gene.

E6. It is a sex-limited trait where *W* (white) is dominant but expressed only in females. In this cross of two yellow butterflies, the male is *Ww* but is still yellow because the white phenotype is limited to females. The female is *ww* and yellow. The offspring would be 50% *Ww* and 50% *ww*. However, all the males would be yellow. Half of the females would be white (*Ww*) and half would be yellow (*ww*). Overall, this would yield 50% yellow males, 25% yellow females, and 25% white females.

E7. The sandy variation may be due to a homozygous recessive allele at one of two different genes in these two varieties of sandy pigs. Let's call them genes *A* and *B*. One variety of sandy pig could be *aaBB* and the other *AAbb*. The F_1 generation in this cross would be heterozygotes for both genes and are all red. This tells us that the *A* and *B* alleles are dominant. In the F_2 generation, 6 out of 16 will be homozygous for either the *aa* or *bb* alleles and become sandy. One out of 16 will be doubly homozygous and be white. The remaining 9 will contain at least one dominant allele for both genes.

E8. One parent must be *RRPp*. The other parent could be *RRPp* or *RrPp*. All the offspring would inherit (at least) one dominant *R* allele. With regard to the other gene, 3/4 would inherit at least one copy of the dominant *P* allele. These offspring would have a walnut comb. The other 1/4 would be homozygous *pp* and have a rose comb (because they would also have a dominant *R* allele).

E9. The yellow squash has to be *wwgg*. It has to be *ww* because it is colored, and it has to be *gg* because it is yellow. Since the cross produced 50% white and 50% green offspring, the other parent (i.e., the white squash) must be *WwGG*. The cross would produce 50% offspring that are *WwGg* (white) and 50% that are *wwGg* (green).

E10. Let's use the letters *A* and *B* for these two genes. Gene *A* exists in two alleles, which we will call *A* and *a*. Gene *B* exists in two alleles, *B* and *b*. The uppercase alleles are dominant to the lowercase alleles. The true-breeding long-shaped squash is *aabb* and the true-breeding disk-shaped is *AABB*. The F_1 offspring are *AaBb*. You can construct a Punnett square to determine the outcome of self-fertilization of the F_1 plants. The Punnett square will have 16 boxes.

To get the disk-shaped phenotype, an offspring must inherit at least one dominant allele from both genes.

$$1\ AABB + 2\ AaBB + 2\ AABb + 4\ AaBb = 9 \text{ disk-shaped offspring}$$

To get the round phenotype, an offspring must inherit at least one dominant allele for one of the two genes but must be homozygous recessive for only one of the two genes.

1 *aaBB* + 1 *AAbb* + 2 *aaBb* + 2 *Aabb* = 6 round-shaped offspring

To get the long phenotype, an offspring must inherit all recessive alleles: 1 *aabb*

E11. It is because they both have one copy of the X^{w-e} allele, an allele that produces a little pigment. The X^w allele does not produce any pigment in the female.

E12. You would expect the alleles with intermediate pigmentation to exhibit a gene dosage effect because these are the ones that are not making a maximum amount of pigment. Alleles such as ivory, pearl, and apricot would be the best candidates. The alleles producing a darker reddish phenotype may not produce a gene dosage effect because a large amount of pigment is already made. To test this idea, you could set up a series of crosses, like the ones described in conceptual question C18, and then analyze the amount of pigment in the eyes of the offspring.

E13. For each of the three crosses we expect a 1:1 ratio, based on the hypothesis that the eosin and white alleles are X-linked alleles of the same gene, and that there is a gene dosage effect. The observed and expected values are as follows:

Observed	*Expected*
225 red eyes	216 red eyes
208 white eyes	216 white eyes
679 red eyes	713 red eyes
747 eosin eyes	713 eosin eyes
694 light-eosin eyes	636 light-eosin eyes
579 light-eosin eyes	636 light-eosin eyes

If we plug these values into the chi square equation (described in Chapter 2), we obtain a value of 14.3. With 5 degrees of freedom, this value lies between 0.05 and 0.01. At the 1% confidence limit, we would accept our hypothesis. At the 5% confidence limit, however, we would reject our hypothesis. Fortunately, many other experiments confirmed the idea that the white and eosin alleles are X-linked alleles in the same gene, and that they exhibit a gene dosage effect. Based on this experiment alone, however, the results would not be completely convincing.

E14. In this cross, we expect that there will be a 9:7 ratio between red and white. In other words, 9/16 will be red and 7/16 will be white. Since there are a total of 345 plants, the expected values are

$$9/16 \times 345 = 194 \text{ red}$$

$$7/16 \times 345 = 151 \text{ white}$$

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

$$\chi^2 = \frac{(201-194)^2}{194} + \frac{(144-151)^2}{151}$$

$$\chi^2 = 0.58$$

With 1 degree of freedom, our chi square value is too small to reject our hypothesis. Therefore, we accept that it may be correct.

E15. The results obtained when crossing two F_1 offspring appear to yield a 9:3:3:1 ratio, which would be expected if eye color is affected by two different genes that exist in dominant and recessive alleles. Neither gene is X linked. Let pr^+ represent the red allele of the first gene and *pr* the purple allele. Let sep^+ represent the red allele of the second gene and *sep* the sepia allele.

The first cross is: *prpr sep⁺sep⁺* × *pr⁺pr⁺sep sep*

All the F_1 offspring would be *pr⁺pr sep⁺sep*. They have red eyes because they have a dominant red allele for each gene. When the F_1 offspring are crossed to each other, the following results would be obtained:

♀ \ ♂	pr⁺sep⁺	pr⁺sep	pr sep⁺	pr sep
pr⁺sep⁺	pr⁺pr⁺ sep⁺sep⁺ — Red	pr⁺pr⁺ sep⁺sep — Red	pr⁺pr sep⁺sep⁺ — Red	pr⁺pr sep⁺sep — Red
pr⁺sep	pr⁺pr⁺ sep⁺sep — Red	pr⁺pr⁺ sep sep — Sepia	pr⁺pr sep⁺sep — Red	pr⁺pr sep sep — Sepia
pr sep⁺	pr⁺pr sep⁺sep⁺ — Red	pr⁺pr sep⁺sep — Red	pr pr sep⁺sep⁺ — Purple	pr pr sep⁺sep — Purple
pr sep	pr⁺pr sep⁺sep — Red	pr⁺pr sep sep — Sepia	pr pr sep⁺sep — Purple	pr pr sep sep — Pur/sepia

In this case, one gene exists as the red (dominant) or purple (recessive) allele and the second gene exists as the red (dominant) or sepia (recessive) allele. If an offspring is homozygous for the purple allele, it will have purple eyes. Similarly, if an offspring is homozygous for the sepia allele, it will have sepia eyes. An offspring that is homozygous for both recessive alleles has purplish sepia eyes. To have red eyes, it must have at least one copy of the dominant red allele for both genes. Based on an expected
9 red : 3 purple : 3 sepia : 1 purplish sepia, the observed and expected numbers of offspring are as follows:

Observed	*Expected*
146 purple eyes	148 purple eyes ($791 \times 3/16$)
151 sepia eyes	148 sepia eyes ($791 \times 3/16$)
50 purplish sepia eyes	49 purplish sepia eyes ($791 \times 1/16$)
<u>444 red eyes</u>	445 red eyes ($791 \times 9/16$)
791 total offspring	

If we plug the observed and expected values into our chi square formula, we obtain a chi square value of about 0.11. With 3 degrees of freedom, this is well within our expected range of values, so we cannot reject our hypothesis that purple and sepia alleles are in two different genes, and that these recessive alleles are epistatic to each other.

E16. Since the results of the first cross produce offspring with red eyes, it suggests that the vermilion allele and purple allele are not alleles of the same gene. The results of the second cross indicate that the vermilion allele is X linked, since all the male offspring had vermilion eyes, just like their mothers. Let pr^+ represent the red allele of the first gene and pr the purple allele. Let X^{v+} represent the red allele of the second gene and X^v the vermilion allele.

For the first cross: the male parents are $pr^+pr^+X^v\,Y$ and the female parents are $prpr\,X^{v+}X^{v+}$. The F_1 offspring are shown in this Punnett square.

♀ \ ♂	pr⁺X^v	pr⁺Y
prX^{v+}	pr⁺pr X^{v+}X^v — Red	pr⁺pr X^{v+}Y — Red
prX^{v+}	pr⁺pr X^{v+}X^v — Red	pr⁺pr X^{v+}Y — Red

For the second cross: the male parents are $prpr X^{v+}Y$ and the female parents are $pr^+pr^+X^v X^v$. The F_1 offspring are shown in this Punnett square.

	♂ prX^{v^+}	prY
♀		
pr^+X^v	pr^+pr $X^{v^+}X^v$ Red	pr^+pr X^vY Vermillion
pr^+X^v	pr^+pr $X^{v^+}X^v$ Red	pr^+pr X^vY Vermillion

Overall, the results of these two crosses indicate that the purple allele is autosomal, and the vermilion allele is X linked. To confirm this idea, the vermilion males could be crossed to homozygous wild-type females. The F_1 females should have red eyes. If these F_1 females are crossed to wild-type males, half of their sons should have vermilion eyes, if the gene is X linked. To verify that the purple allele is in an autosomal gene, a purple male could be crossed to a homozygous wild-type female. The F_1 offspring should all have red eyes. If these F_1 offspring are allowed to mate with each other, they should produce 1/4 purple offspring in the F_2 generation. In this case, the F_2 generation offspring with purple eyes would be both male and female.

E17. To see if the allele is X linked, the pink-eyed male could be crossed to a red-eyed female. All the offspring would have red eyes, assuming that the pink allele is recessive. When crossed to red-eyed males, the F_1 females will produce 1/2 red-eyed daughters, 1/4 red-eyed sons, and 1/4 pink-eyed sons if the pink allele is X linked.

If the pink allele is X linked, then one could determine if it is in the same X-linked gene as the white and eosin alleles by crossing pink-eyed males to white-eyed females. (Note: We already know that white and eosin are alleles of the same gene.) If the pink and white alleles are in the same gene, the F_1 female offspring should have pink eyes (assuming that the pink allele is dominant over white). However, if the pink and white alleles are in different genes, the F_1 females will have red eyes (assuming that pink is recessive to red). This is because the F_1 females will be heterozygous for two genes, $X^{w+p}X^{wp+}$, in which the X^{w+} and X^{p+} alleles are the dominant wild-type alleles that produce red eyes, and the X^w and X^p alleles are recessive alleles for these two different genes, which produce white eyes and pink eyes, respectively.