**Experimental Questions**

E1. **Answer**: 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. **Answer**: Two redundant genes 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.

E3. **Answer**: 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).

E4. **Answer**: 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.

E5. **Answer**: 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.
E6. **Answer:** In general, you cannot distinguish between autosomal and pseudoautosomal inheritance from a pedigree analysis. Mothers and fathers have an equal probability of passing the alleles to sons and daughters. However, if an offspring had a chromosomal abnormality, you might be able to tell. For example, in a family tree involving the Mic2 allele, an offspring that was X0 would have less of the gene product and an offspring that was XXX or XYY or XXY would have extra amounts of the gene products. This may lead you to suspect that the gene is located on the sex chromosomes.

E7. **Answer:** 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 F1 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 F2 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. **Answer:** 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. **Answer:** 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. Because 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. **Answer:** 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 F1 offspring are $AaBb$. You can construct a Punnett square, with 16 boxes, to determine the outcome of self-fertilization of the F1 plants.

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

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

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:

$$1\ aabb = 1\ long-shaped\ offspring$$
E11. **Answer:** In this cross, we expect a 9:7 ratio between red and white flowers. In other words, 9/16 will be red and 7/16 will be white. Because there are a total of 345 plants, the expected values are

\[
\frac{9}{16} \times 345 = 194 \text{ red}
\]

\[
\frac{7}{16} \times 345 = 151 \text{ white}
\]

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

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

\[
\chi^2 = 0.58
\]

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

E12. **Answer:** 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: $prpr sep^+ sep^+ \times pr^+ pr sep sep$  

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:
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:

<table>
<thead>
<tr>
<th>Observed</th>
<th>Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>146 purple eyes</td>
<td>148 purple eyes (791 × 3/16)</td>
</tr>
<tr>
<td>151 sepia eyes</td>
<td>148 sepia eyes (791 × 3/16)</td>
</tr>
<tr>
<td>50 purplish sepia eyes</td>
<td>49 purplish sepia eyes (791 × 1/16)</td>
</tr>
<tr>
<td>444 red eyes</td>
<td>445 red eyes (791 × 9/16)</td>
</tr>
<tr>
<td>791 total offspring</td>
<td></td>
</tr>
</tbody>
</table>

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.

E13. Answer: Because 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, because 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 $pr^+pr^+X^vY$ and the female parents are $prprX^v+X^v+$. The F1 offspring are shown in this Punnett square.

For the second cross: the male parents are $prprX^v+Y$ and the female parents are $pr^+pr^+X^vX^v$. The F1 offspring are shown in this Punnett square.
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 F₁ females should have red eyes. If these F₁ 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 F₁ offspring should all have red eyes. If these F₁ offspring are allowed to mate with each other, they should produce 1/4 purple offspring in the F₂ generation. In this case, the F₂ generation offspring with purple eyes would be both male and female.

E14. Answer: 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 F₁ 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 F₁ 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 F₁ females will have red eyes (assuming that pink is recessive to red).

This is because the F₁ females will be heterozygous for two genes, \( X^w+P \ X^wp^+ \), in which the \( X^w+ \) and \( Xp^+ \) alleles are the dominant wild-type alleles that produce red eyes, and the \( X^w \) and \( Xp \) alleles are recessive alleles for these two different genes, which produce white eyes and pink eyes, respectively.

E15. Answer: In X-linked recessive inheritance, it is much more common for males to be affected. In autosomal recessive inheritance, there is an equal chance of males and females being affected (unless there is a sex influence, in which an allele is dominant in one sex but recessive in the opposite sex). For X-linked dominant inheritance, affected males would produce 100% affected daughters and not transmit the trait to their sons. This would not be true for autosomal dominant traits, where there is an equal chance of males and females being affected.