Principles of Biology - Genetics Problems

GAMETE PRODUCTION

1) Which gametes can individuals with each of the following genotypes produce?
   a) AA  
      answer: 1 kind of gamete (A)
   b) aa  
      answer: 1 kind of gamete (a)
   c) Aa  
      answer: 2 kinds of gametes (A & a)
   d) AaBB  
      answer: 2 kinds of gametes (AB & aB)
   e) AaBb  
      answer: 4 kinds of gametes (AB, Ab, aB & ab)

SIMPLE MENDELIAN

2) Black fur in guinea pigs is a dominant trait. White fur is the alternative recessive trait. When a true-breeding black guinea pig is crossed to a white one,

   a) What fraction of the F1 offspring is expected to be heterozygous?
      answer: 100% will be heterozygous
      \[ BB \times bb = 100\% \text{ Bb (F}_1\text{ generation)} \]

   b) What fraction of the F2 offspring is expected to be heterozygous?
      answer: 50% of the F2 will be heterozygous
      The \( F_1 \) individuals are all heterozygous (Bb). They can each produce two types of gametes, B \& b which can combine with each other during fertilization to form the \( F_2 \) individuals (see Punnett square below).

   c) What fraction of the black \( F_2 \) offspring is expected to be heterozygous?
      answer: 2/3 (or 66%) of the black \( F_2 \) individuals will be heterozygous
      BB and Bb genotypes both would present as a black phenotype. It is twice as likely that a Bb individual will be produced as it is that a BB individual will result from the \( F_1 \times F_1 \) mating. Since you would then expect 2 Bb offspring for every 1 BB offspring that is produced, you can say that 2/3 (or 66%) of the black \( F_2 \) individuals will be heterozygous.
3) A couple of black guinea pigs of the same genotype were mated and produced 29 black and 9 white offspring. What you would predict the genotypes of the parents to be?

answer: They would both be heterozygous (Bb)

Hint: Try all combinations of matings with black parents (BB or Bb). Then determine the probability of phenotypes among the offspring.

BB x BB = all BB (all black)
Bb x BB = ½ BB; ½ Bb (all black)
Bb x Bb = ¼ BB; ½ Bb; ¼ bb (3/4 black; ¼ white)

4) Consider a gene with two alleles, B and b.

a) List all the matings (i.e., parental genotypes) that could produce a heterozygous child.

answer: BB x bb
Bb x Bb
Bb x bb
BB x Bb

b) Which mating in your list gives the greatest proportion of heterozygous offspring?

answer: BB x bb (would give 100% Bb)

The others would result in only 50% Bb:

5) The absence of legs in mice has been attributed to a recessive allele. A normal male is mated with a normal female and they produce a legless offspring. The same two parents are mated again. What is the chance of their next offspring being legless?

answer: If two normal parents produce a homozygous recessive offspring, they must both be heterozygotes (Ll). Since they are both heterozygous, the chance that their next offspring will be legless (ll) is 25%.

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>l</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>LL (legs)</td>
<td>Ll (legs)</td>
</tr>
<tr>
<td>l</td>
<td>Ll (legs)</td>
<td>ll (legless)</td>
</tr>
</tbody>
</table>

(note: the fact that they already have a legless offspring does not affect the probability of their having a 2nd legless offspring)
TESTCROSS

6) If a black female guinea pig is test-crossed and produces 2 offspring in each of 3 litters, all of which are black, what is her probable genotype?

\[ \text{answer: She is most likely BB, since all of her offspring from her testcross were black. If she were Bb, then 50\% of her offspring should be white.} \]

CODOMINANCE

7) The amount of chlorophyll in snapdragons is controlled by a pair of codominant alleles. Dark green is governed by the genotype: \( \text{C}^1\text{C}^1 \). Light green is governed by the genotype: \( \text{C}^1\text{C}^2 \). White is governed by the genotype \( \text{C}^2\text{C}^2 \).

a) When light green snapdragons are crossed among themselves, what genotypic and phenotypic ratios are expected among their progeny?

\[ \text{answer: } \text{C}^1\text{C}^2 \times \text{C}^1\text{C}^2 \]

\begin{align*}
\text{C}^1 & \quad \text{C}^2 \\
\text{C}^1 & \quad \text{C}^1, \text{C}^1\text{C}^2, \text{C}^1\text{C}^2 \\
\text{C}^2 & \quad \text{C}^1\text{C}^2, \text{C}^1\text{C}^2 \\
\text{C}^2 & \quad \text{C}^1\text{C}^2, \text{C}^2\text{C}^2
\end{align*}

Genotypic ratio: \( \frac{1}{4} \text{C}^1\text{C}^1: \frac{1}{2} \text{C}^1\text{C}^2: \frac{1}{4} \text{C}^2\text{C}^2 \)

Phenotypic ratio: \( \frac{1}{4} \) dark green: \( \frac{1}{2} \) light green: \( \frac{1}{4} \) white

b) If dark green snapdragons are crossed with white snapdragons, what genotypic and phenotypic ratios are expected among their progeny?

\[ \text{answer: } \text{C}^1\text{C}^1 \times \text{C}^2\text{C}^2 \]

\begin{align*}
\text{C}^1 & \\
\text{C}^2 & \quad \text{C}^2
\end{align*}

Genotypic ratio: all \( \text{C}^1\text{C}^2 \)

Phenotypic ratio: all light green

8) Yellow coat color in guinea pigs is produced by the homozygous genotype \( \text{C}^y\text{C}^y \), cream color by the heterozygous genotype \( \text{C}^y\text{C}^w \), and white by the homozygous genotype \( \text{C}^w\text{C}^w \). What genotypic and phenotypic ratios are matings between cream-colored individuals likely to produce?

\[ \text{answer: } \text{C}^y\text{C}^w \times \text{C}^y\text{C}^w \]

\begin{align*}
\text{C}^y & \quad \text{C}^w \\
\text{C}^y & \quad \text{C}^y\text{C}^w, \text{C}^y\text{C}^w \\
\text{C}^w & \quad \text{C}^y\text{C}^w, \text{C}^w\text{C}^w
\end{align*}

Genotypic ratio: \( \frac{1}{4} \text{C}^y\text{C}^y: \frac{1}{2} \text{C}^y\text{C}^w: \frac{1}{4} \text{C}^w\text{C}^w \)

Phenotypic ratio: \( \frac{1}{4} \) yellow: \( \frac{1}{2} \) cream: \( \frac{1}{4} \) white
**SEX-LINKED**

9) In fruit flies the most common eye color is red. A mutation (or allele) of the gene for eye color produces white eyes. The gene is located on the X chromosome.

a) What is the probability that a heterozygous red-eyed female fruit fly mated with a white-eyed male will produce any white-eyed offspring?

*Answer: \(X^+X^w \times X^wY\)*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(X^+)</td>
<td>(X^w)</td>
</tr>
<tr>
<td>(X^w)</td>
<td>(X^+X^w)</td>
</tr>
<tr>
<td>(Y)</td>
<td>(X^+Y)</td>
</tr>
</tbody>
</table>

\(X^wX^w\) and \(X^wY\) will both have white eyes, so 50% of the total offspring will be expected to have white eyes.

b) What is the probability that the mating in (a) will produce any white-eyed females?

*Answer: 25% of the total offspring are white-eyed females (however, 50% of all females are white-eyed).*

c) What is the probability that this same mating will produce any white-eyed males?

*Answer: 25% of the offspring are white-eyed males.*

10) In fruit flies the most common eye color is red. A mutation (or allele) of the gene for eye color produces white eyes. The gene is located on the X chromosome.

a) What is the probability that a heterozygous red-eyed female fruit fly mated with a red-eyed male will produce any white-eyed offspring?

*Answer: \(X^+X^w \times X^+Y\)*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(X^+)</td>
<td>(X^w)</td>
</tr>
<tr>
<td>(X^+)</td>
<td>(X^+X^w)</td>
</tr>
<tr>
<td>(Y)</td>
<td>(X^+Y)</td>
</tr>
</tbody>
</table>

Only \(X^wY\) will have white eyes, so 25% of the total offspring will be expected to have white eyes.

b) What is the probability that the mating in (a) will produce any white-eyed females?

*Answer: There are two genotypes produced among the females. \(X^+X^w\) and \(X^+X^{w+}\). Neither of these genotypes would produce a white-eyed phenotype. Therefore, 0% of the offspring will be white-eyed females.*

c) What is the probability that this mating will produce any white-eyed males?

*Answer: There are two genotypes produced among the males. \(X^wY\) and \(X^+Y\). \(X^wY\) males will have white eyes and \(X^+Y\) males will have red eyes.*
Therefore, 50% of all males and 25% of all offspring will be white-eyed males.

11) A female who is the carrier of color blindness marries a male who is not color blind. Color blindness is a sex-linked trait. What is the probability that any of the offspring produced have the following traits?

<table>
<thead>
<tr>
<th></th>
<th>$X^c$</th>
<th>$X$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X$</td>
<td>$X^cX$</td>
<td>$XX$</td>
</tr>
<tr>
<td>$Y$</td>
<td>$X^cY$</td>
<td>$XY$</td>
</tr>
</tbody>
</table>

a) color blindness

Answer: There are four possible genotypes for all offspring: $X^cY$, $XY$, $X^cX$, $XX$. Only the $X^cY$ genotype would have a color blind phenotype. Therefore, 25% of the total offspring would be expected to be color blind.

b) color blind males

Answer: There are two possible genotypes for males: $X^cY$ and $XY$. Only the $X^cY$ genotype would have a color blind phenotype. Therefore, 50% of the males would be expected to be color blind. (Or 25% of total)

c) color blind females

Answer: There are two possible genotypes for females: $X^cX$ and $XX$. Neither genotype would present as a color blind phenotype. Therefore, 0% of the females would be expected to be color blind.