Section 16.1 - Genetics of Inheritance

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Homework Review

Define what is meant by the following terms:

Traits: Characteristic that can be identified (short, tall, green, yellow)

Heredity: passing of traits from generation to generation.
Define what is meant by the following terms:

Genetics: The branch of biology dealing with the principles of variation and inheritance.

Gene: A section of DNA which controls the expression of a trait.

Allele: Variations of genes.
Homework Review

Define what is meant by the following terms:

Variations: Forms of a trait, in other words, the different ways in which a trait may be expressed.

Purebred: Descended from ancestors with similar characteristics. (ex: a pea plant which is purebred green)

True Breeding: Consistently produce the same characteristics in offspring.
Monohybrid Cross

Read Pages 529-530, and define the following terms:

P Generation - Parent generation
- Usually true-breeding

F1 Generation - First generation of offspring

F2 Generation - Second generation of offspring

Dominant - Characteristic which will always be expressed if the allele is present

Recessive - Characteristic that is only expressed if no other alleles are present

Homozygous - Both genes for a trait are of the same variety

Heterozygous - Two different alleles for a trait are present
Pea plants have several traits that are easy to identify. For example, the plants may be either tall or short. This characteristic is controlled by a single gene that has two alleles.

Tall is dominant, so we use the notation: \( T \) (tall allele) \( t \) (short allele)
A true breeding tall plant will be homozygous tall.

TT
(both genes are the same allele)

A short plant will be homozygous short.

tt
(both genes are the same allele)
A heterozygous plant carries one of each allele.

Tt

- because the allele for tall is dominant, the tall characteristic is expressed.
Monohybrid Cross

Describe what is meant by the Principle of Dominance and the Law of Segregation.

**Principle of Dominance:**
When individuals of contrasting traits are crossed, the offspring will show only the dominant trait.

**Law of Segregation:**
Characteristics are controlled by pairs of genes, which are separated during gamete formation.
TT

TT

Tt (all offspring)

tt

| P |

F₁
Bio 621 Notes
for Thursday, December 6, 2007

Start Here!
Definitions

Two important terms in genetics are *genotype* and *phenotype*.

**Genotype**

refers to the genetic makeup of an organism. In our mice, for example, a white mouse will always have the genotype **bb**. A black mouse may have the genotype **BB** or **BB**.

**Phenotype**

refers to the physical appearance of a trait in an organism. For example, a mouse may be heterozygous for fur color, with the genotype **Bb**, but the phenotype will be that the mouse is black.
Monohybrid Cross

Use a diagram to outline the following hypothetical crossing.

One species of mouse may be either black or white, with fur color being controlled by a single gene. The allele for black fur is dominant to the allele for white fur.

If a purebred black mouse is bred to a purebred white mouse, what will the physical color of the offspring be? What will their genetic makeup be?

Use a diagram to explain your answer!

This was done at the end of class on Monday..review the solution on the following page...
All offspring of this cross will be **heterozygous** (*genotype*) and have **black fur** (*phenotype*)

```
bb x BB    →    3 F₁
  Bb

{3 P}
```
Monohybrid Cross

Use a diagram to outline the following hypothetical crossing.

If two F1 mice from the previous example are crossed, what ratio of physical characteristics and genetic makeup would you expect to find in the offspring?

Use a diagram to explain your answer!
This cross will result in two phenotypes, with 75% being black and 25% being white. However, there are three possible genotypes: 25% homozygous black; 50% heterozygous (but still having black fur, the dominant trait); and 25% homozygous white.
Punnett Squares

A Punnett Square is a convenient way to organize the possible combinations of alleles in a crossing.
Punnett Squares

In the previous example using mice, the Punnet square allows us to easily see the possible results of an $F_1$ cross.

You need to know the genotype of both parents to fill in the possible gametes.

Since the $F_1$ mice are all heterozygous, they could each produce a $B$ or a $b$ gamete (ie: a gamete carrying either the dominant or recessive allele)
Punnett Squares

Fill in the square, and analyze the results.

By filling in the possible combinations, you can see that:

1/4 offspring are BB, or homozygous dominant, and will have black fur

2/4, in other words 1/2, are Bb, or heterozygous, and will have black fur

1/4 offspring are bb, or homozygous recessive, and will have white fur
Sample Problem

Use Punnet Squares to solve the following problem:

In fruit flies, red eyes are dominant over white eyes. Show the F1 generation results of a cross between a purebreeding red-eyed fly and a purebreeding white-eyed fly. Describe the ratio of phenotypes and genotypes in this generation.

Then, show the F2 generation results, and describe the ratio of phenotypes and genotypes in this generation.

Give about 5 minutes to complete this question, then review the solution on the following pages.
Sample Problem - Solution

Because both parents are **pure-breeding**, they are both **homozygous**.
As a result, each gamete from either parent will carry the same allele.

Therefore, all offspring in the F₁ generation are **heterozygous**, and will display the **dominant trait**...in this case, **red eyes**.

- **R** - red eyes allele
- **r** - white eyes allele

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100% of the F1 offspring will display the red-eyed phenotype and be heterozygous (genotype)
Sample Problem - Solution

When you cross two of the F₁ flies, both parents are heterozygous.

In the F₂ generation, you get a distinct pattern of phenotypes, with 75% showing the dominant trait and 25% showing the recessive trait.

However, when you look at the genotypes, you see that only 25% are homozygous dominant; 50% are heterozygous; and 25% are homozygous recessive.

\[
\frac{3}{4} \text{ - Red eyes } \quad \frac{1}{4} \text{ white eyes}
\]
Sample Problem - Solution

\[
\begin{array}{ccc}
R & r \\
R & RR & Rr \\
r & Rr & rr \\
\end{array}
\]

\[
\frac{1}{4} (25\%) \quad \frac{2}{4} (50\%) \quad \frac{1}{4} (25\%)
\]
In Class Assignment and Homework

Read Section 16.1, pages 526-534

Complete the Sample Problem activity on page 533, and Questions #8, 10, 11, 13, and 15 on page 535

Bring two quarters to class on Friday
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8 offspring all brown eyed.
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**Phenotype:**
- 75% normal
- 25% albino

25% homozygous dominant
50% heterozygous
25% homo rec.
Genotype: SS
   Ss

Sarah: SS

Bud: SS
Yy × yy

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50% yellow
50% green
Phenotype - **tall** pea plant.

Tall is dominant to short.

\[ T \text{ - tall allele} \]
\[ t \text{ - short allele} \]

What is the genotype of a **tall** pea plant? \[ TT \text{ or } Tt \]
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100% of offspring are tall.

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50% of offspring are tall. 50% of offspring are short.
Not a good test case.

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100% tall

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Title: Dec 7-1:12 PM (39 of 110)
Determining Genotypes - Test Cross

If you look at a fruit fly, can you determine the genotype for eye color by observing the phenotype?

You can if the fly is white-eyed, because the white-eye allele is recessive...so the only way a fly could have white eyes would be if it was homozygous.

\[ rr \]
But what if the fly has red eyes?

There are two possible phenotypes that produce red eyes:
Determining Genotypes - Test Cross

In this case, the genotype can be determined by performing a test cross. This involves crossing the fly with a fly which is homozygous recessive for the trait being observed. By observing the phenotypes of the offspring, you can then determine the genotype of the unknown parent.

Use Punnett squares to predict the percentages of phenotypes if a white-eyed (homozygous recessive) female fly is crossed with a red eyed male.

You will need to create one Punnett square to show the results if the male is homozygous, and one to show the expected results if the male is heterozygous.
Determining Genotypes - Test Cross
Sample Problem

In cats, long hair is recessive to short hair. 

1) A true-breeding short-haired male is mated to a true-breeding long-haired female. What will their kittens look like?

2) If you performed a test cross on a short-haired female cat, what phenotype should the male cat have? Why?

3) If the testcross resulted in eight kittens, what ratios of phenotypes would you expect if the female was homozygous? Heterozygous?

4) What if the testcross resulted in seven short-haired kittens, and one long-haired kitten? How can you explain these results?
SS x SS

\[ \begin{array}{cc}
SS & ss \\
Ss & ss
\end{array} \]

100% Ss

\[ \begin{array}{ccc}
SS & Ss & Ss \\
S & ss & ss
\end{array} \]

50% Short
50% Long
Test: Thursday,
Dec 13
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<tbody>
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<td>♂</td>
<td>Ss</td>
<td>Ss</td>
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- S - short hair
- s - long hair.

♀ - ss
♂ - SS

- homozygous dominant
- homozygous recessive

All kittens are heterozygous short-haired.
Long-haired parent: ss
Short-haired parent: SS
all offspring are short-haired

50% short-haired
50% long-haired
B - black
b - white
BB -
bb
Bb
Phenotype: Dwarf bull.
Genotype: Dd

Phenotype: Dwarf cows.
Genotype: Dd
<table>
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<th>Genotypes</th>
<th>Frequency</th>
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<td>dwarf</td>
</tr>
<tr>
<td>50%: homozygous</td>
<td>normal tall</td>
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<tr>
<td>25%: homozygous</td>
<td>dwarf</td>
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</tbody>
</table>
Determining Genotypes - Test Cross
Section 16.2 - Complex Inheritance Patterns

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Complex Patterns of Inheritance

Multiple Traits

It is possible to look at more than one trait at a time.

For example, in pea plants you could look at both color and the shape of the seed.

Color is controlled by a single gene with two alleles, Y (yellow) and y (green)

Shape is controlled by a single gene with two alleles, R (round) and r (wrinkled)

What are the results of crossing a true-breeding yellow, round plant with a true-breeding green, wrinkled plant?
Yellow, Round plant (phenotype)

YY RR (genotype)

YR - all gametes
Green, Wrinkled (phenotype)

yy rr (genotype)

g and r - all gametes
YR

YyRr

generation

all offspring are heterozygous for both traits.

Phenotype: Yellow, Round
Chickens can have brown or white feathers, with brown color dominant. They can also have long or short tail feathers, with short feathers dominant. What are the phenotypes & genotypes of chickens produced by crossing a brown, short-tailed male with a white, long-tailed female.
♀
B: brown
S: short
♀ white, long
♀ bbSS
♂
B: brown
S: short
♂ - long tail
♀ BS BbSS
♀ s
♀ 65
What if a homozygous white, long-tailed male was crossed with a homozygous brown, heterozygous short-tailed female.

\[ \begin{array}{c|c}
0^2 bbss & 0 BBSs \\
\downarrow \quad \text{(gametes)} & BS \text{ or } Bs
\end{array} \]
<table>
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<th>Phenotype:</th>
<th>BbSs</th>
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<tr>
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<td>Brown, short-tailed 50%</td>
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Multiple Traits

First, you have to determine the possible alleles.
Multiple Traits

What are the phenotypes and genotypes of the offspring?
Multiple Traits

What percentages of phenotypes and genotypes would you expect in the F$_2$ generation if you crossed two plants from the F$_1$ generation?

Again, the first step is to determine the possible alleles.

\[ Yy \quad Rr \]
\[ yR \quad yr \]

Possible gametes:
\[ YR \quad Yr \quad yR \quad yr \]
Law of Independent Assortment

Inheritance of alleles for one trait does not affect the inheritance of alleles for another trait.

In other words, alleles for different characteristics are passed on to the offspring independently of one another, so that the offspring may have combinations that are different from either of the parents.

What process in cell division allows for this to happen?

Can you think of a situation where it would be more likely that alleles would be kept together?
Multiple Traits

Create a Punnett square to determine the phenotypes and genotypes of the F2 generation.

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</tbody>
</table>
Dark - D  light - d

Rough - R  Smooth - r

Dd Rr \( \Rightarrow \) \text{ genotype (heterozygous)}

Phenotype: Dark, rough fur.
9/16 Dark, rough
3/16 Dark, smooth
3/16 Light, rough
1/16 Light, smooth
Curly - C  straight - c
TongueCurler - T  non-curler - t

Curly hair  TongueCurler  Curly hair
CCTT  non-TongueCurler  CCTT
CcTT  CcTT  CcTT  CcTt  CcTt  CcTt

Title: Dec 11-1:02 PM (73 of 110)
CCTT x CCtt

\[ \begin{array}{c|c}
Ct & \text{All children} \\
CT & \text{homozygous curly, heterozygous tongue.} \\
& \text{Phenotype: Curly haired, tongue curlers.}
\end{array} \]
<table>
<thead>
<tr>
<th></th>
<th>C&lt;sub&gt;t&lt;/sub&gt;</th>
<th>c&lt;sub&gt;t&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>CCT&lt;sub&gt;t&lt;/sub&gt;</td>
<td>CcT&lt;sub&gt;t&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
black fur dominant

B

BB

BB

black

Bb

black

bb

white
<table>
<thead>
<tr>
<th>Bb</th>
<th>bb</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B</em></td>
<td><em>b</em></td>
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</tbody>
</table>

- **B** × **bb**

<table>
<thead>
<tr>
<th>Bb</th>
<th>Bb</th>
<th>Bbb</th>
<th>Bbb</th>
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</table>

- 100% black
- 50% white

50% white
Test Cross with Multiple Traits

A test cross when looking at multiple traits is the same as in a single trait. The only difference is, you will cross your unknown genotype with an individual that is homozygous recessive for both of the characteristics you are looking at.

How can you tell an individual has a homozygous recessive genotype?

Show the recessive trait.
Test Cross with Multiple Traits

What are the possible genotypes of a yellow, round pea plant?

Yellow is dominant
Yellow - Y
Green - y

Round is dominant
Round - R
Wrinkled - r

YYRR  YyRR  YyRr  YYRRr

What would the results of each testcross be?
Test Cross with Multiple Traits

Testcross of round, yellow pea plant. What are the results if the genotype is YYRR?

---

100% yellow round.
**Test Cross with Multiple Traits**

Testcross of round, yellow pea plant.  
What are the results if the genotype is YYRr?

50% yellow, round  
50% yellow, wrinkled.

<table>
<thead>
<tr>
<th>Y</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>r</td>
</tr>
</tbody>
</table>

YRYyRr
Yr Yyrr

50% yellow, round  
50% yellow, wrinkled.
Test Cross with Multiple Traits

Testcross of round, yellow pea plant. What are the results if the genotype is YyRR?

50% yellow round
50% green round

<table>
<thead>
<tr>
<th>Yy</th>
<th>Rr</th>
<th></th>
</tr>
</thead>
</table>
|   |   | Yyrr
|   | Rr | yyrR
| Yy |   | YyRr
|   | Rr | yyRr

50% yellow round
50% green round
Test Cross with Multiple Traits

Testcross of round, yellow pea plant.
What are the results if the genotype is YyRr?

<table>
<thead>
<tr>
<th></th>
<th>Jr</th>
<th>Yr</th>
<th>Yr</th>
<th>Yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>yellow, round</td>
<td>YR</td>
<td>YrRr</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>yellow, wrinkled</td>
<td>Yr</td>
<td>Yr</td>
<td>YrRr</td>
</tr>
<tr>
<td>25%</td>
<td>green, round</td>
<td>yR</td>
<td>yR</td>
<td>yyRr</td>
</tr>
<tr>
<td>25%</td>
<td>green, wrinkled</td>
<td>yy</td>
<td>yy</td>
<td>yyRr</td>
</tr>
</tbody>
</table>

yrr
Multiple Traits Sample Problem

In cats, black color is dominant to a special gene which produces cream-colored cats with dark legs, faces and tails (Siamese cats, in case you don’t recognize it). Length of fur is controlled by a single gene with two alleles; long hair is dominant to short hair.

What are the F1 expected results of a cross between a true-breeding long-haired black cat and a true-breeding short-haired Siamese colored cat?

\[
\begin{array}{c|c|c}
\text{Hair length} & \text{long} & \text{short} \\
\text{Color} & \text{black} & \text{Siamese} \\
\end{array}
\]

\[
\begin{array}{c}
LLBB \times llbb \\
\rightarrow \text{heterozygous} \\
\text{phenotype: long haired/ black}
\end{array}
\]
Multiple Traits Sample Problem

If two F1 cats are crossed, what genotype and phenotype ratios would you expect in the F2 offspring?

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<th>LB</th>
<th>LLb</th>
<th>LBb</th>
<th>LLbb</th>
<th>LBb</th>
<th>LLBb</th>
<th>LLbb</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/16</td>
<td>long-haired black</td>
<td>LB</td>
<td>LLBB</td>
<td>LLBb</td>
<td>LBb</td>
<td>L1Bb</td>
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<tr>
<td>3/16</td>
<td>long/ Siamese</td>
<td>Lb</td>
<td>LLBB</td>
<td>L1bb</td>
<td>L1Bb</td>
<td>L1bb</td>
<td></td>
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<tr>
<td>3/16</td>
<td>short/ black</td>
<td>1B</td>
<td>L1BB</td>
<td>L1Bb</td>
<td>1BB</td>
<td>1Bb</td>
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<tr>
<td>1/16</td>
<td>short/ Siamese</td>
<td>1b</td>
<td>L1Bb</td>
<td>L1bb</td>
<td>1Bb</td>
<td>Lb</td>
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Title: Oct 16-9:43 AM (86 of 110)
Multiple Traits Sample Problem

How could you determine the phenotype of a long-haired black cat?

Show all possible combinations, and the expected results?
Multiple Traits Sample Problem

Solution:
Incomplete Dominance

Not all traits are completely dominant or recessive. In some cases, neither allele is dominant...in these cases, a heterozygous individual will display a blending of the two traits.

This is called **incomplete dominance**.
Incomplete Dominance

For example, some flowers have petal color controlled by a single gene with two alleles: one coding for red color, the other for white. If the individual is homozygous for either allele, this is the petal color that will be displayed.

Phenotype: red petals  
Genotype: RR  
Phenotype: white petals  
Genotype: rr
Incomplete Dominance

However, if the individual is heterozygous, neither of these traits is displayed...instead, the flower shows a blending of red and white, resulting in pink petals.

Phenotype:

Genotype: \( Rr \)
Codominance

Codominance is similar to incomplete dominance, except both traits are dominant. In this case, homozygous individuals display one trait, while heterozygous individuals display both traits, not as a blending of the two, but showing both characteristics partially.
Codominance

For example, color in one type of cow is controlled by a single gene with two alleles, one coding for brown fur and one for white fur.

Homozygous cows are either brown or white.
Codominance

However, heterozygous cows will display brown and white patches, rather than being light brown all over.

Phenotype: mottled
Genotype: BW
1) A dihybrid cross is made of pea plants. Purple flowers (P) are dominant and white flowers are recessive. Tall plants (T) are dominant and short plants are recessive. Both parents are heterozygous for both traits. Prepare a Punnett square to determine the phenotype ratios of the offspring.

What Mendelian law does this ratio demonstrate?
Homework

1) Solution

Both parents' genotype: \( PpTt \)

Phenotype Ratios:

- Purple, Tall: 9
- Purple, Short: 3
- White, Tall: 3
- White, Short: 1

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<td>( PpTT )</td>
<td>( PpTt )</td>
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Homework

2) A rose-combed rooster is mated with two rose-combed hens.

Hen A produces 14 chicks, all rose-combed.

Hen B produces 9 chicks, 7 of which are rose-combed and 2 single-combed.

What are the likely genotypes of the parent birds?
First: We believe rose combs must be Dominant (D).

- Since two rose-combed individuals can produce single comb offspring, they must be able to carry the allele without expressing it...

ie: Single-comb is recessive.
Single is dominant

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Note: ss represents the genotype for single color, and S represents the allele for single color.
Homework

2) Solution

Second: We believe the male must be heterozygous.
- A recessive allele must be passed from both parents to be expressed.
- Since crossing with one hen results in all rose combs, while crossing with a different hen results in an approx. 3:1 ratio of the rooster must carry the recessive allele.
Homework

2) Solution

Rose: R  Single: r

100% Rose

75% Rose

25% Single

Hen A is homozygous dominant.

Hen B is heterozygous (7:2 is approx 3:1, or 75:25)
Sample Problem

You know that one type of flower has petal color determined by a single gene with two alleles, red or white, and they display incomplete dominance. If a red flower is crossed with a white flower, what are the genotypes and phenotypes of the F\textsubscript{1} generation offspring?

\[
\begin{align*}
\text{Red} &\rightarrow RR \\
\text{White} &\rightarrow WW
\end{align*}
\]

What are the expected genotypes and phenotypes of the F\textsubscript{2} offspring if two pink flowers are cross pollinated?

\[
\begin{align*}
\text{Red} &\rightarrow RW \\
\text{White} &\rightarrow WW
\end{align*}
\]

All Pink
**Sample Problem**

**Solution**

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<td>RW</td>
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100% of offspring are **pink**

(Red: R  White: W)

(i.e., heterozygous)
### Sample Problem

#### Solution

**Ratios**

<table>
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<tr>
<th>Genotype</th>
<th>Phenotype</th>
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<tbody>
<tr>
<td>Homozygous</td>
<td>Red</td>
<td>$\frac{1}{4}$ (25%)</td>
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<tr>
<td>Homozygous</td>
<td>White</td>
<td>$\frac{1}{4}$ (25%)</td>
</tr>
<tr>
<td>Heterozygous</td>
<td>Pink</td>
<td>$\frac{2}{4}$ (50%)</td>
</tr>
</tbody>
</table>

```
<table>
<thead>
<tr>
<th>R</th>
<th>W</th>
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<td>RR</td>
<td>RW</td>
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<tr>
<td>RW</td>
<td>WW</td>
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</table>
```
If you had a brown cow and wanted to know its genotype, how would you perform a testcross?

A testcross is not necessary if traits show incomplete or co-dominance...because the phenotype tells you the genotype!
Multiple Alleles

Not all traits are controlled by genes with only two alleles; some have multiple alleles.

In humans, for example, the A, B and O blood types are determined by three alleles, two of which are co-dominant and one of which is recessive.

The \text{IA} allele results in blood type A; the \text{IB} allele results in blood type B; and the \text{i} allele, being recessive, results in blood type O.

Remember that the blood types are determined by antigens on the surface of blood cells. These antigens are proteins, so the gene codes for the production of these antigens...in type O, the gene does not code for production of an antigen.
**Multiple Alleles**

List all possible genotypes which could result in the following phenotypes (blood types).

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Genotype</th>
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<tbody>
<tr>
<td>A</td>
<td>( I^A I^A ); ( I^A i )</td>
</tr>
<tr>
<td>B</td>
<td>( I^B I^B ); ( I^B i )</td>
</tr>
<tr>
<td>AB</td>
<td>( I^A I^B )</td>
</tr>
<tr>
<td>O</td>
<td>( ii )</td>
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</tbody>
</table>
Assignment: Inheritance of Coat Color in Rabbits

Complete the Thinking Lab on page 543. Be sure to answer all questions completely, including the Punnett squares.
Attachments

Endocrine Gland Function.wpd