

## 2007 7.013 Problem Set 2 KEY

Due before 5 PM on FRIDAY, March 2, 2007.

Turn answers in to the box outside of 68-120.

PLEASE WRITE YOUR ANSWERS ON THIS PRINTOUT.

**1.** Wild-type flies are brown in color. You have discovered a gene that controls body color in flies called gene A. You have two true-breeding mutant strains, both of which have black bodies.

Strain One ( $a_1/a_1$ ) is homozygous for a mutation in gene A that causes a dominant mutant phenotype.

Strain Two ( $a_2/a_2$ ) is homozygous for a mutation in gene A that causes a recessive mutant phenotype.

Group Three are flies that result from mating Strain One to Strain Two.

Group Four are flies that result from mating Strain One to wild-type ( $A/A$ ).

Group Five are flies that result from mating Strain Two to wild-type ( $A/A$ ).

Predict the genotypic ratio and the phenotypic ratio of the offspring resulting from the following crosses. Make sure to label each class in each of your ratios.

**Group Three are  $a_1/a_2$**

**Group Four are  $A/a_1$**

**Group Five are  $A/a_2$**

**(a)** Group Three and Group Five  
Genotypic ratio:

Phenotypic ratio:

**1  $A/a_1$  to 1  $a_1/a_2$  to 1  $a_2/a_2$  to 1  $A/a_2$**

**3 black to 1 brown**

**-----black----- brown**

**This is the result of a cross of  $a_1/a_2$  to  $A/a_2$ .**

**(b)** Strain Two and Group Three  
Genotypic ratio:

Phenotypic ratio:

**1  $a_1/a_2$  to 1  $a_2/a_2$**

**1 black to zero brown**

**-----black-----**

**This is the result of a cross of  $a_1/a_2$  to  $a_2/a_2$ .**

(c) Group Four and Strain Two  
Genotypic ratio:

Phenotypic ratio:

1 A/a<sub>2</sub> to 1 a<sub>1</sub>/a<sub>2</sub>

1 black to 1 brown

brown      black

This is the result of a cross of a<sub>1</sub>/A to a<sub>2</sub>/ a<sub>2</sub>.

(d) Group Four and Group Five  
Genotypic ratio:

Phenotypic ratio:

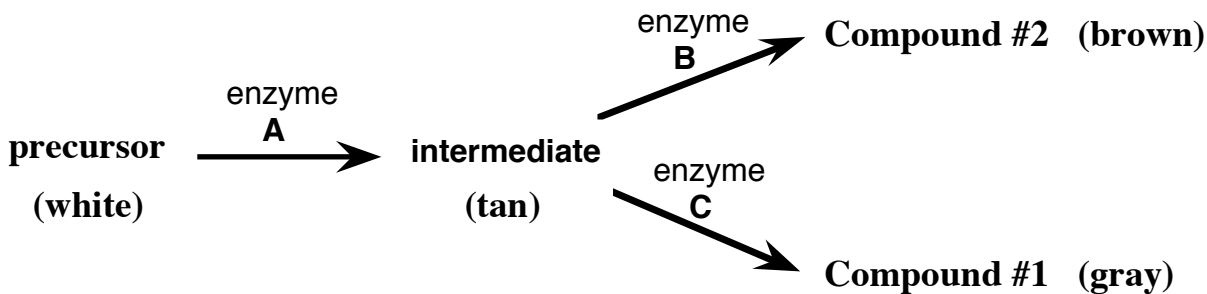
1 A/A to 1 A/a<sub>2</sub> to 1 a<sub>1</sub>/a<sub>2</sub> to 1 A/a<sub>1</sub>

1 black to 1 brown

-----brown-----    ---brown-----

This is the result of a cross of a<sub>1</sub>/A to A/ a<sub>2</sub>.

**2.** Consider a fictitious pathway that controls coat color in the mouse. The mouse genome contains gene A, which encodes enzyme A, an enzyme that converts the precursor (a white compound) to the intermediate (a tan compound). The mouse genome contains gene B, which encodes enzyme B, an enzyme that converts the intermediate to Compound #2 (a brown compound). The mouse genome contains gene C, which encodes enzyme C, an enzyme that converts the intermediate to Compound #1 (a gray compound). Mice that produce both compound #1 and compound #2 are brownish-gray. Genes A, B, and C are all autosomal genes that lie on different mouse chromosomes. Loss-of-function mutations in both homologous versions (maternal and paternal) of any one gene (A, B, or C) causes a recessive phenotype.



Name: \_\_\_\_\_ **KEY** \_\_\_\_\_

(a) Which color coat would each following mouse have? Some are filled in for you.

AABBCC = brownish gray

The introduction tells you that mice that produce both compound #1 and compound #2 are brownish-gray.

aaBBCC = white

Any mouse that is “aa” will be unable to convert the white precursor into the tan intermediate, and thus will never produce any color at all. This same explanation holds for the rest of the answers you had to fill in.

AaBbcc = brownish-tan

AabbCc = grayish-tan

Aabbcc = tan

aaBBcc = white

aabbCc = white

aabbcc = white

(b) Two different true-breeding strains of mice have been isolated; neither strain can produce compound #1 or compound #2. When an individual from one strain is crossed with an individual from the other strain, all of the F1 mice produce both compounds. Write out the genotypes for both P generation strains, and the genotype for the F1 generation. (Use “A,” “B,” and “C” to designate the wild-type alleles and “a,” “b,” and “c” to designate the defective alleles of the three genes.) Also write out the coat color of each group of animals.

	<b>Genotype</b>	<b>Coat Color</b>
<b>P generation, one strain</b>	<u>AAbbcc</u>	<u>tan</u>
<b>P generation, other strain</b>	<u>aaBBCC</u>	<u>white</u>
<b>F1 generation</b>	<u>AaBbCc</u>	<u>Brownish gray</u>

Name: \_\_\_\_\_ KEY \_\_\_\_\_

If neither of the original strains produce compound #1 and neither produce compound #2, then the original strains must be one of the following three genotypes (remember, the two original strains are true-breeding so they are homozygous):

AAbbcc  
 aaBBCC  
 aabbcc  
 aabbCC  
 aaBBcc

If you investigate every pairwise mating, the only one that gives you all brownish gray in the F1 is AAbbcc mated to aaBBCC. To be brownish gray, a mouse must have at least one “A” and at least one “B” and at least one “C” allele.

(c) Two of the F1 mice are crossed to one another. The possible phenotypes for the F2 progeny are shown below. What fraction of the F2 generation will be represented by each phenotype on average? (Note: some fractions in the table may be zero.)

Coat Color	Fraction of F2 that is this coat color
white	<u>16/64</u>
tan	<u>3/64</u>
brown	<u>zero</u>
brownish-gray	<u>27/64</u>
brownish-tan	<u>9/64</u>
grayish-tan	<u>9/64</u>

AaBbCc crossed to AaBbCc gives the following proportion of genotypes (where “A\_” for instance means at least one “A” allele):

A\_B\_C\_ = 3/4 X 3/4 X 3/4 = 27/64 brownish-gray  
 A\_bbC\_ = 3/4 X 1/4 X 3/4 = 9/64 grayish-tan  
 A\_B\_cc = 3/4 X 3/4 X 1/4 = 9/64 brownish-tan  
 A\_bbcc = 3/4 X 1/4 X 1/4 = 3/64 tan  
 aaB\_C\_ = 1/4 X 3/4 X 3/4 = 9/64 white  
 aabbC\_ = 1/4 X 1/4 X 3/4 = 3/64 white  
 aaB\_cc = 1/4 X 3/4 X 1/4 = 3/64 white  
 aabbcc = 1/4 X 1/4 X 1/4 = 1/64 white



(d) The two traits are determined by two completely linked genes on the X chromosome

hairy thick: 0  
 hairy thin: 500  
 hairless thick: 500  
 hairless thin: 0

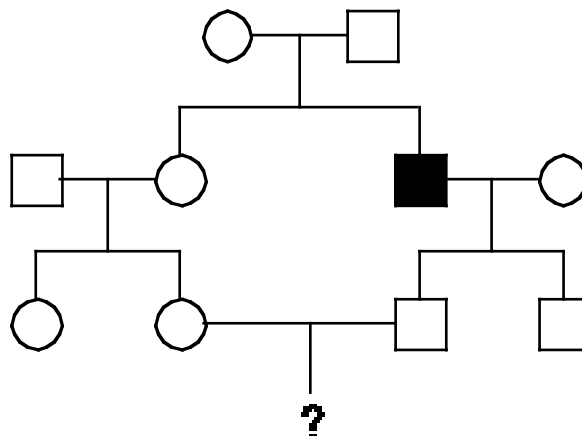
**P generation:**  $X^{hT} X^{hT}$  crossed to  $X^{Ht} Y$   
**F1:**  $X^{Ht} X^{hT}$  crossed to  $X^{ht} Y$   
**F2:**  $X^{Ht} Y$  OR  $X^{hT} Y$   
 -----parentals-----

(e) The two traits are determined by two genes that are 20 cM apart on the X chromosome

hairy thick: 100  
 hairy thin: 400  
 hairless thick: 400  
 hairless thin: 100

**P generation:**  $X^{hT} X^{hT}$  crossed to  $X^{Ht} Y$   
**F1:**  $X^{Ht} X^{hT}$  crossed to  $X^{ht} Y$   
**F2:**  $X^{Ht} Y$  OR  $X^{hT} Y$  OR  $X^{HT} Y$  OR  $X^{ht} Y$   
 -----parentals----- 80%                      -----recombinants----- 20%

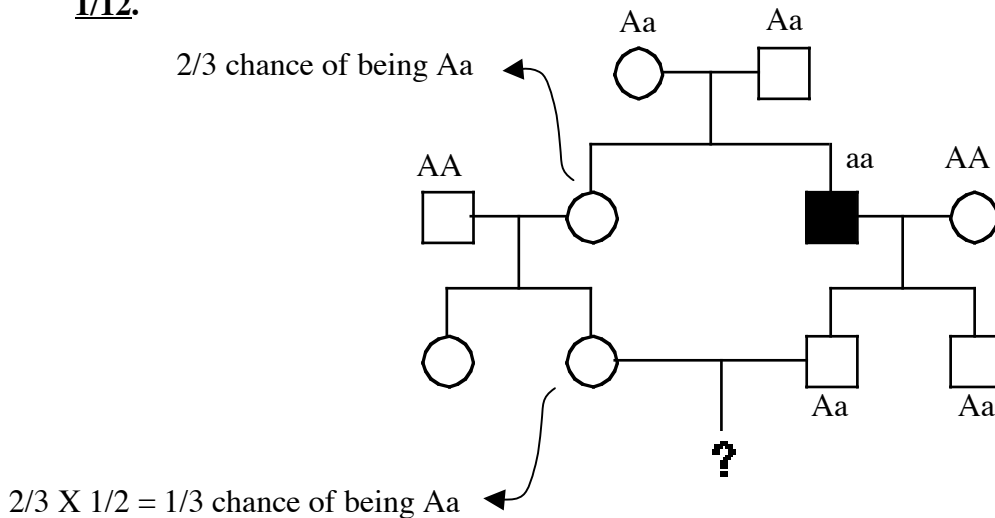
4. You have just been hired as a genetic counselor for a royal family that still engages in a significant amount of inbreeding. As your first assignment, you are presented with the following pedigree where the filled symbol represents a male in the royal family who has a rare disease.



Your job is to calculate the probability that the child indicated by ? will have the disease. To do this, assume that no new mutations arise within the pedigree and that no unrelated individual is a carrier (because this is a very rare disease). Also assume complete penetrance.

(a) If the disease is autosomal recessive, what is the probability that the child indicated by the ? will have the disease?

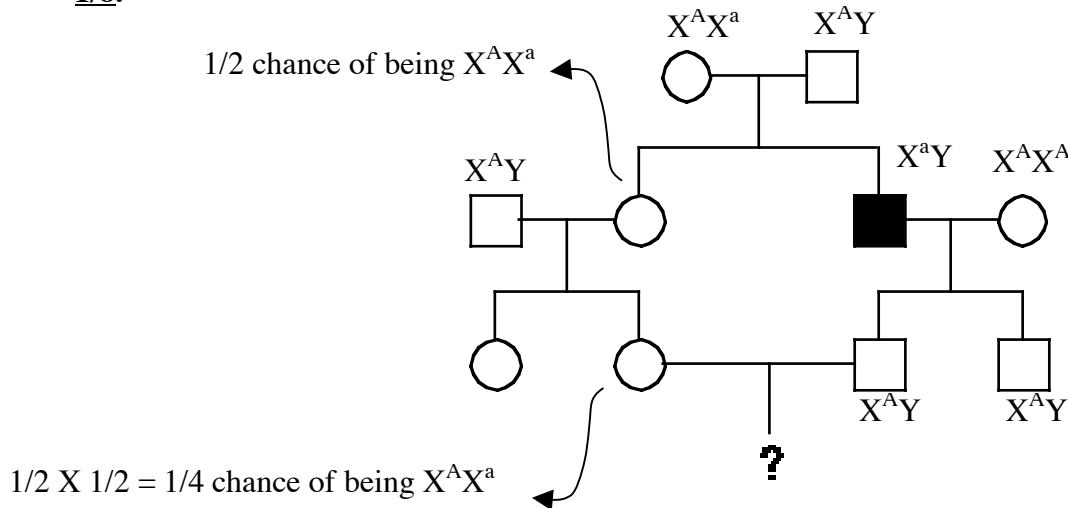
1/12.



If an Aa mom mates with an Aa father and has a child, then that child has a 1/4 chance of being affected. Thus the total chance is 1/4 times the chance that the mom of ? is Aa, which = 1/4 X 1/3 = 1/12.

(b) If the disease is X-linked recessive, what is the probability that a child will be born with the disease if that child is born male?

1/8.

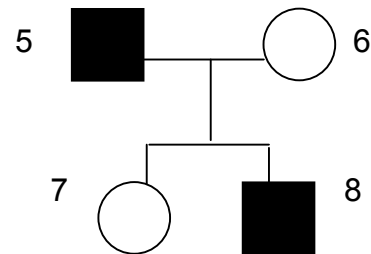
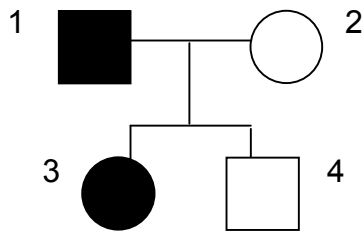


If an  $X^A X^a$  mom mates with an  $X^A Y$  father and has a male child, then that male child has a  $1/2$  chance of being affected. Thus the total chance is  $1/2$  times the chance that the mom of ? is  $X^A X^a$ , which =  $1/2 \times 1/4 = 1/8$ .

(c) If the disease is X-linked recessive, what is the probability that a child will be born with the disease if that child is born **female**?

**Zero.** If an  $X^A X^a$  mom mates with an  $X^A Y$  father and has a female child, then that female child has a zero chance of being affected because the father will always give the allele that does not confer the rare recessive trait.

**5.** This problem involves two families, each of which contains individuals that express the same rare trait due to having the same rare mutation. The families are diagrammed below — individuals are numbered, and those expressing the rare trait are represented by the filled symbols. For each possible mode of inheritance listed below, state what the probability is that the child will express the rare trait. Assume that no new mutations arise within the pedigree, and assume complete penetrance.



(a) Assume that the rare trait is **autosomal recessive**. Consider the possible matings described below. For each, calculate the probability that the child will have the rare trait.

- Female 6 and Male 4: 25%
- Female 6 and Male 1: 50%
- Female 7 and Male 1: 50%
- Female 3 and Male 5: 100%

If the trait is autosomal recessive, then the genotypes would be:

- Female 2 = Aa
- Female 3 = aa
- Female 6 = Aa
- Female 7 = Aa
- Male 1 = aa
- Male 4 = Aa
- Male 5 = aa
- Male 8 = aa

Name: \_\_\_\_\_ KEY \_\_\_\_\_

(b) Now assume that the rare trait is **autosomal dominant**. Again for each of the possible matings given below, calculate the probability that the child will have the rare trait.

Female 6 and Male 4: 0%

Female 6 and Male 1: 50%

Female 7 and Male 1: 50%

Female 3 and Male 5: 75%

If the trait is autosomal dominant, then the genotypes would be the following (where we are using “A” as the mutant allele that confers the rare dominant trait):

Female 2 = aa

Female 3 = Aa

Female 6 = aa

Female 7 = aa

Male 1 = Aa

Male 4 = aa

Male 5 = Aa

Male 8 = Aa

(c) Finally, assume that the rare trait is **X-linked recessive**. For each of the possible matings given below, calculate the probability that the child will have the rare trait. Explicitly give a probability for sons and a probability for daughters in any case where the probabilities for a boy or a girl having the trait differ.

Female 6 and Male 4: 50% for a boy, 0% for a girl

Female 6 and Male 1: 50% (same for a boy or a girl)

Female 7 and Male 1: 50% (same for a boy or a girl)

Female 3 and Male 5: 100% (same for a boy or a girl)

If the trait is X-linked recessive, then the genotypes would be:

Female 2 =  $X^A X^a$

Female 3 =  $X^a X^a$

Female 6 =  $X^A X^a$

Female 7 =  $X^A X^a$

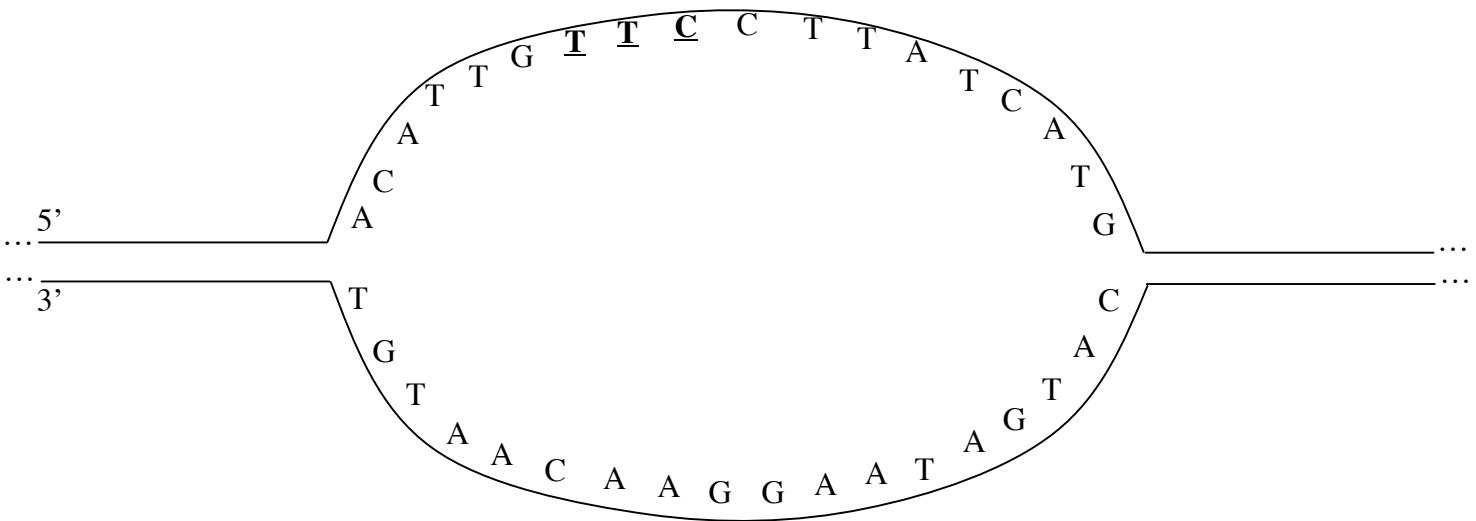
Male 1 =  $X^a Y$

Male 4 =  $X^A Y$

Male 5 =  $X^a Y$

Male 8 =  $X^a Y$

6. Below is shown a picture of a replication bubble.



(a) The primer 5'-GAA-3' is being used to replicate this piece of DNA. Would that primer anneal to the upper strand of DNA in the picture or the lower strand?

**Upper.** The sequence 5'-GAA-3' would basepair to its antiparallel complement, 3'-CTT-5', which only exists at the site bolded above.

(b) Write what the product of DNA replication would be if the first five nucleotides had been added onto this primer by DNA polymerase. Label the 5' and 3' ends. Make sure to include the primer.

**5'-GAACAATGT-3'.** Replication proceeds 5'--> 3', such that nucleotides are always added on to the 3' end of the primer. This is DNA replication, so the nucleotides added on to the RNA primer are deoxyribonucleotides.

(c) Would that strand that you have drawn in part (b) be a leading strand or a lagging strand?

**Leading.** DNA replication occurs in a “leading fashion” when the direction of fork opening by helicase is the same direction as replication is occurring. This allows replication to keep on going continuously, as helicase unwinds more and more DNA. Helicase would be unwinding the relevant fork (the one on the left) in this direction:

←

to expand this replication bubble, and our strand is replicating this way:

←

so it must be a leading strand.