

EXERCISE 11 – MENDELIAN GENETICS PROBLEMS

These problems are divided into subdivisions composed of problems that require application of a specific genetic principle. These problems are intended to complement the lecture portion of this course; specifically, the material described in lecture is to be applied to solve these problems. The answers are provided in Appendix A. You are strongly advised against consulting this appendix before you have made a serious attempt to answer a problem.

A. Monohybrid Crosses

1. In *Coleus*, some plants have shallowly crenated edges and others have deeply incised leaves. A cross is made between homozygous deep and shallow individuals. The shallow trait is dominant.
 - a. Using *S* and *s* to symbolize the genes for this trait, give the phenotypic and genotypic ratios for the F_1 generation.
 - b. If self pollination is allowed, what is the phenotypic ratio for the F_2 generation?
2.
 - a. In a pea plant that breeds true for tall, what possible gametes can be produced? Use the symbol *D* for tall, *d* for dwarf.
 - b. In a pea plant that breeds true for dwarf, what possible gametes will be produced?
 - c. What will be the genotype of F_1 offspring from a cross between these two types?
 - d. Assuming that the allele for tall is dominant, what will be the phenotype of F_1 offspring from a cross between these two types?
 - e. What will be the probable distribution of traits in the F_2 generation? (Illustrate with a Punnett square).
3. The ability to taste a bitter chemical, phenylthiocarbamide (PTC), is due to a dominant gene. Use *T* and *t* to symbolize the two alleles of this gene.
 - a. What is the genotype of a nontaster? What are the possible genotypes of a taster?
 - b. Could a person with two tasters as parents be a non-taster? How?
4. A woman heterozygous for polydactyly (extra fingers and toes), a dominant trait, is married to a normal man. What is the probability of producing an offspring that has extra fingers or toes?
5. Parents who do not have Tay Sachs disease produce a child who has this terrible affliction. What are the chances that each child born of this union will be affected?
6. In human beings, ability to curl the tongue into a U-shaped trough is a heritable trait. "Curlers" always have at least one curler parent, but "noncurlers" may occur in families where one or both parents are curlers. Using *C* and *c* to symbolize this trait, what is the genotype of a noncurler?

7. Albinism, the total lack of pigment, is due to a recessive gene. A man and woman plan to marry and wish to know the probability of their having any albino children. What are the probabilities if:
 - a. both are normally pigmented, but each has one albino parent.
 - b. the man is an albino, the girl is normal, but her father is an albino.
 - c. the man is an albino and the girl's family includes no albinos for at least three generations.

8. In a certain plant, both purple x purple and purple x blue yield purple and blue colored progeny, but blue x blue gives rise only to blue.
 - a. What does this tell you about the genotypes of blue- and purple-flowered plants?
 - b. Which gene is dominant?

9. Two short-haired female cats are mated to the same long-haired male. Several litters are produced. Female No. 1 produced eight short-haired and six long-haired kittens. Female No. 2 produced 24 short-haired ones and no long-haired. From these observations, what deductions can be made concerning hair-length inheritance in these animals? Assuming the allelic pair S and s , give the likely genotypes of the two female cats and the male.

10. In human beings, a downward pointed frontal hairline ("widow's peak") is a heritable trait. A person with a widow's peak always has at least one parent who also has this trait, whereas persons with a straight frontal hairline may occur in families in which one or even both parents have widow's peak. When both parents have a straight frontal hairline, all children also have a straight hairline. Using W and w to symbolize genes for this trait, what is the genotype of an individual without widow's peak?

11. Rh negative children (those not producing rhesus antigen D) may be born to either Rh positive or Rh negative parents, but Rh positive children always have at least one Rh positive parent. Which phenotype is due to a dominant gene?

B. Dihybrid Crosses

1. In the fruit fly *Drosophila melanogaster*, vestigial wings and hairy body are produced by two recessive genes located on different chromosomes. The normal alleles, long wings and hairless body, are dominant. Give the genotype and phenotype of F_1 progeny obtained from a cross between a vestigial-winged, hairy male and a normal, homozygous female. If the F_1 from this cross are permitted to mate randomly among themselves, what phenotypic ratio would be expected in the F_2 generation?

2. In peas, a gene for tall plants (T) is dominant over its allele for short plants (t). The gene for smooth peas (S) is dominant over its allele for wrinkled peas (s). The genes are not linked. Calculate both phenotypic and genotypic ratios for the results of each of the following crosses:
 - a. $TtSs \times TtSs$
 - b. $Ttss \times ttss$
 - c. $ttSs \times Ttss$
 - d. $TtSS \times ss$

3. In a particular species of flower, tall is dominant to short, and orange petals are dominant to the recessive white color. Use T and t to symbolize the alleles for height, and F and f

to symbolize the alleles for flower color. A homozygous tall white flower is crossed with a flower heterozygous for both traits. List the genotypes of the parents. What are the F_1 genotypic and phenotypic ratios?

4. How many phenotypic classes are produced by a dihybrid test-cross where one parent is heterozygous for both pairs of genes?
5. In hogs, an allele that produces a white belt around the animal's body (W) is dominant over its allele for a uniformly colored body (w). The dominant allele of another gene (F) produces a fusion of the two hoofs on each foot. Suppose a uniformly-colored hog homozygous for fused hoofs is mated with a normal-footed hog homozygous for the belted character.
 - a. What are the genotypes of the parents?
 - b. What are the genotypic and phenotypic ratios of the F_1 ?
 - c. If the F_1 were allowed to interbreed, what are the genotypic and phenotypic ratios of the F_2 ?
6. In watermelons, the genes for green color and for short length are dominant over their alleles for striped color and for long length. Suppose a plant with long striped fruit is crossed with a plant heterozygous for both of these characters. What phenotypes would this cross produce and in what ratios?

C. Modifications of Complete Dominance

Incomplete Dominance

1. The so-called "blue" (really gray) Andalusian variety of chicken is produced by a cross between the black and white varieties, both of which breed true (i.e., both are homozygous). What color chickens (and in what proportions) would you expect if you crossed two blues? a blue and a black?
2. In four o'clock, red color exhibits incomplete dominance over white; when both exist together, the flowers are pink.
 - a. In a cross between a red flower and a white one, what is the genotype of the offspring?
 - b. What is the genotypic ratio of the F_2 generation if two of the F_1 from (a) are crossed?
 - c. List the genotypes of offspring produced by a cross between the F_1 generation and red parent.
3. It has long been known in the field of human genetics that wavy hair is the expression of a heterozygous genotype in which the allele for straight hair is paired with the allele for curly hair. Lucinda Lovelee married Larry Legg. Both of these charmers have wavy hair. What is the probability that their offspring, the littlest Legg, will have:
 - a. wavy hair?
 - b. curly hair?
 - c. straight hair?

4. If pale colored horses are crossed with chestnut-colored horses to produce "palomino", an intermediate coat color:
 - a. What type of expression is suggested?
 - b. A number of matings between palominos produced 19 pale, 21 chestnut, and 44 palominos. Does this evidence support or contradict your answer to (a)? Why?

Codominance

1. For each of the following pairs of parental genotypes, calculate the phenotypic ratios for the F_1 generation.
 - a. $I^A I^A \times ii$
 - b. $I^A I^A \times I^A I^B$
 - c. $I^A I^A \times I^B i$
 - d. $I^A I^A \times I^A i$
 - e. $I^A i \times I^A i$
 - f. $I^A i \times I^A I^B$
 - g. $I^A i \times ii$
2. If Mr. and Mrs. Fecundity, both having blood type B, have 12 children, 3/4 of whom are type B and 1/4 of whom are O, what are the genotypes of the parents?
3. A family of six includes four children, each of whom has a different blood type: A, B, AB and O. What are the genotypes of parents for this trait?
4. A man with blood type B, with one parent of blood type O, marries a woman with blood type AB. What will be the theoretical percentage of their children with blood type B?
5. Mrs. Smith and Mrs. Doe were roommates at Harris Hospital and both had daughters at about the same time. After Mrs. Smith took Susie home, she became convinced that the babies had been switched. Blood tests were performed with the following results:
 Mr. and Mrs. Smith were both type AB;
 Mr. and Mrs. Doe were both type A;
 Susie Smith was type A and Debbie Doe was type O.

 Had a switch occurred?
6. Mortimer has type B blood. His wife Murgatroyd is unsure of her blood type. If their first child, Magnifica, is type B, their second offspring, Maximum, is AB and the twins, Maud and Lyn, are A, can you determine the genotypes of Mort and Murg?
7. In a well-publicized paternity case, the following facts were unearthed; the mother, a strikingly beautiful, twice-convicted axe murderess, is blood type A, her child, Lizzie, is type O, and the alleged father, a mild-mannered felon, is type B. Could he be the father? Explain. Is there any chance that little Lizzie, the "Bad Seed", will grow up to be a missionary lady?

D. Lethal Alleles

1. Cystic fibrosis is caused by a recessive lethal gene and can be detected by an excess concentration of chloride in sweat. If a sweat test reveals a man to be heterozygous and his wife to be homozygous normal, what are the chances that their children will have the disease? Could any of their grandchildren have the disease?

2. In humans, sickle-cell anemia is caused by a recessive lethal allele Hb^S ; individuals who are $Hb^A Hb^S$ have sickle-cell trait, but are healthy.
 - a. What is the probability of two heterozygous individuals giving birth to a child with sickle-cell trait?
 - b. What is the probability of two heterozygous individuals giving birth to a child with sickle-cell anemia?
 - c. If a normal $Hb^A Hb^A$ individual receives a blood transfusion from a $Hb^A Hb^S$ individual (heterozygous for sickle cell) what are the chances that the $Hb^A Hb^A$ man and his $Hb^A Hb^A$ wife will have $Hb^A Hb^S$ children?
3. Albinism in corn plants is caused by a recessive lethal gene that results in death before maturity. What will the adult phenotypic ratio be for the F_1 generation of heterozygous parents?
4. Huntington's chorea is a dominant lethal in humans. The disease does not appear until later in life, so that afflicted individuals may already have produced children. What are the F_1 genotypic and phenotypic ratios of parents who are homozygous dominant and heterozygous?

E. Sex-linked Genes

1. Red-green color blindness is inherited as a sex-linked recessive. If a color-blind woman marries a man who has normal vision, what would be the expected phenotypes of their children with reference to this character?
2. Suppose that gene b is sex-linked, recessive, and embryonic lethal. A man marries a woman who is heterozygous for this gene. If this couple had many normal children, what would be the predicted sex ratio of these children?
3. A man and his wife both have normal color vision, but a daughter has red-green color blindness, a sex-linked recessive trait. The man sues his wife for divorce on grounds of infidelity. Can genetics provide evidence supporting his case?
4. In the mouse, the dominant sex-linked gene B results in a short, crooked tail. Its recessive allele b produces a normal tail. If a normal-tailed female is mated with a bent-tailed male, what phenotypic ratio should occur in the F_1 generation?
5. In cats, a gene for coat color is sex-linked. Cats homozygous for allele A have yellow coats; those homozygous for allele a have black coats; and heterozygotes have tortoise-shell coats. What type(s) of offspring would result from a mating of a black male and a tortoise-shell female? Is it possible to obtain a tortoise-shell male?
6. On the X chromosome of *Drosophila* there may occur a recessive gene l , which is lethal in the larval stage. A heterozygous female is crossed to a normal male; what F_1 adult sex phenotypic ratio results?

F. Recombination

1. In *Drosophila melanogaster*, there is a dominant gene for gray body color and another dominant gene for normal wings. The recessive alleles of those two genes result in black body color and vestigial wings, respectively. Flies homozygous for gray body and normal wings were crossed with flies that had black bodies and vestigial wings. The F₁ progeny were then test-crossed, with the following results:

Gray body, normal wings	236
Black body, vestigial wings	253
Gray body, vestigial wings	50
Black body, normal wings	61

Would you say that these two genes are linked? If so, how many units apart are they on the chromosome?

2. A series of dihybrid test crosses gives the following crossover frequencies: A-B, 3%, A-C, 13%; B-C, 10%
 - a) What is the gene sequence?
 - b) Another cross gives a frequency of 19% for A-D. Can you locate the position of D in the sequence?
 - c) If the crossover for C-D is found to equal 6%, where would gene D be located?
3. In the nematode *Caenorhabditis elegans*, *dpy-18* and *unc-32* are recessive alleles which confer the phenotypes of a dumpy body and uncoordinated movement, respectively. A test cross is performed, and yields the following progeny:

<u>Phenotype</u>	<u># Progeny</u>
Dpy Unc	409
Wild type	391
Dpy	106
Unc	93

Are the genes linked? If so, how many units apart are they on the chromosome?

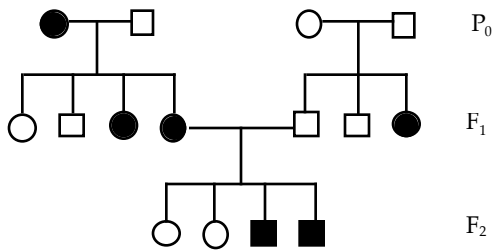
4. In the same organism, *dpy-5* and *unc-4* are another set of recessive alleles which confer the same properties. A similar test cross is performed.

<u>Phenotype</u>	<u># Progeny</u>
Dpy Unc	243
Wild Type	251
Unc	247
Dpy	249

Are the genes linked? If so, how many units apart are they on the chromosome?

G. Pedigree Analyses

1. The diagram shows three generations of the pedigree of deafness in a family. Black circles and squares indicate deaf persons. ● and ○ indicate a female; ■ and □ indicate a male. Is the condition of deafness in this pedigree inherited as (1) a dominant autosomal characteristic, (2) a recessive autosomal characteristic, (3) a sex-linked dominant characteristic, or (4) a sex-linked recessive characteristic?

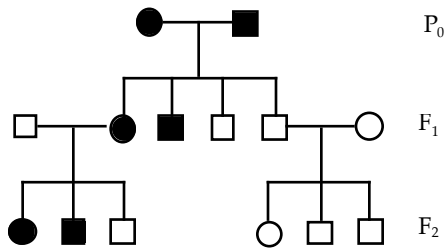


2. In the following pedigree charts,

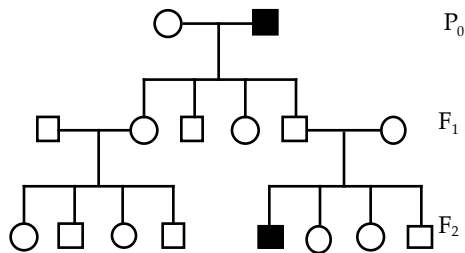
● = afflicted female
 ■ = afflicted male
 ○ = normal female
 □ = normal male

Indicate the pattern of inheritance.

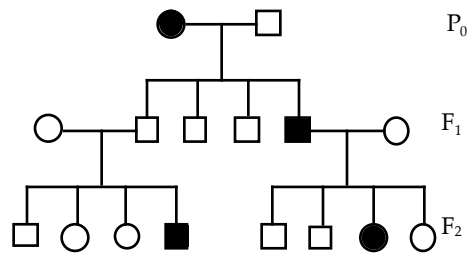
A.



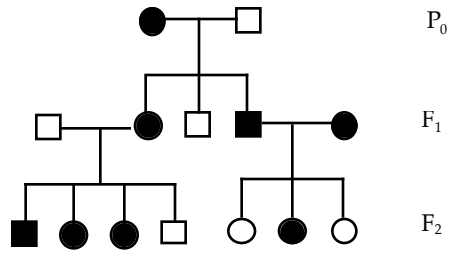
B.



C.



D.



APPENDIX -----Answers to Genetics Problems

A. Monohybrid Crosses

1. a. $SS \times ss$
Shallow deep

genotypic = all Ss
phenotypic = all shallow
- b. F_2 Genotypic = 1 : 2 : 1 or $1/4 SS: 1/2 Ss: 1/4 ss$

Phenotypic = 3 : 1 or $3/4$ shallow; $1/4$ deep

2. a. D b. d c. Dd d. All tall e. F_2

	D	d
D	DD	Dd
d	Dd	dd

3. a. $tt; TT$ or Tt
b. Yes, if both his or her parents were heterozygous.
4. 50%
5. 25%
6. cc
7. a. 25% b. 50%
c. Probably zero: the girl's family history suggests that she is homozygous normal.
8. a. Purple is heterozygous; blue is homozygous b. Purple
9. Short hair is the dominant trait. Genotypes: Female No. 1 is Ss ; Female No. 2 is SS ; the male is ss .
10. ww - homozygous recessive
11. Rh^+ is dominant.

B. Dihybrid Crosses

1. The genes may be symbolized as:

 v = vestigial h = hairy body
 V = long wing H = hairless body

The genotypes of the parents are: Male vvhh, Female VVHH.

One hundred percent of the F₁ will be VvHh (normal long wing, hairless body).

The F₂ phenotypic ratio is 9 normal long wing, hairless body; 3 vestigial wing, hairless body; 3 normal long wing, hairy body; 1 vestigial wing, hairy body. This can be obtained by multiplying the two phenotypic ratios times one another.

The phenotypic ratio for wings is 3 normal long : 1 vestigial. The phenotypic ratio for hair is 3 hairless : 1 hairy. Since the two traits segregate independently -

$$\begin{array}{r} 3 : 1 \\ \underline{3 : 1} \\ 9 : 3 : 3 : 1 \end{array}$$

2. The two ratios can again be multiplied, since the genes (S+T) are not linked.

<u>Genotypic Ratio</u>	<u>Phenotypic Ratio</u>
a) 1TT : 2Tt : 1tt <u>1SS : 2Ss : 1ss</u> 1TTSS : 2TtSS : 1ttSS 2TTSs : 4TtSs : 2 ttSs short, smooth 1TTss : 2Ttss : 1 ttss	3 tall : 1 short <u>3 smooth : 1 wrinkled</u> 9 tall, smooth : 3 short, smooth: 3 tall, wrinkled : 1 short, wrinkled
b) 1Tt : 1tt <u>1ss</u> 1Ttss : 1ttss	1 tall : 1 short <u>all wrinkled</u> 1 tall, wrinkled : 1 short, wrinkled
c) 1tt : 1Tt <u>1Ss : 1ss</u> 1ttSs : 1TtSs 1ttss : 1Ttss	1 tall : 1 short <u>1 smooth : 1 wrinkled</u> 1 tall, smooth : 1 short, smooth : 1 tall, wrinkled:1 short, wrinkled
d) 1Tt <u>1Ss</u> 1TtSs	All tall <u>All smooth</u> All tall, smooth

3. The parental genotypes are: TTff x TtFf

The F₁ genotypic ratio is: 1 : 1 : 1 : 1

The F₁ phenotypic ratio is: 1 : 1

4. Four. For example: CcBb x ccbb ---Cc Bb

Cc bb

cc Bb

cc bb

5. a) The parental genotypes are: ww FF x WW ff

- b) All the F_1 's are $WwFf$ (white belted with fused hoofs).
- c) The genotypic ratio is: 1:2:1:2:4:2:1:2:1
The phenotypic ratio is: 9:3:3:1

6. 1 green short: 1 green long: 1 striped short: 1 striped long

C. Modifications of Complete Dominance

Incomplete Dominance

1. The genotypes of the black and white may be represented as BB and bb , respectively. A "blue" chicken has the genotype Bb . Crossing two blues would produce 1/4 black, 1/2 blue, and 1/4 white. Crossing a blue and a black would produce 1/2 blue and 1/2 black.
2. a. If the parental genotypes are RR and rr , the offspring would be Rr .
b. 1 RR : 2 Rr : 1 rr
c. 1 RR : 1 Rr
3. The genotypes may be symbolized as follows: AA = straight hair, aa = curly hair, Aa = wavy hair.
a. 50%
b. 25%
c. 25%
4. a. incomplete dominance
b. We suspect palominos to be heterozygous. If they are crossed, a 1:2:1 ratio should result. It does, which supports our answer.

Codominance

1. a. 100% A
b. 50% A, 50% AB
c. 50% AB, 50% A
d. 100% A
e. 75% A, 25% O
f. 50% A, 25% AB, 25% B
g. 50% A, 50% O
2. $I^B i \times I^B i$
3. Parents must be $I^A i$ and $I^B i$
4. 50%. The parental genotypes are: $I^B i \times I^A I^B$
5. Mr. and Mrs. Smith must both have genotypes $I^A I^B$. Mr. and Mrs. Smith could not have given birth to Debbie Doe - Type O. A switch had not occurred.
6. Mortimer is $I^B i$. Murgatroyd is either $I^A i$ or $I^A I^B$.

7. The mother may be $I^A i$, while the father is $I^B i$. Consequently, there would be a 25% chance of the child being type O. Criminal behavior has never been found to be correlated with chromosomal inheritance. With the proper environment, Little Lizzie could turn out to be an angel.

D. Lethal Alleles

1. None of their children will have cystic fibrosis. Their grandchildren could have the disease if the heterozygous children marry other heterozygotes.
2. a) $Hb^A Hb^S$ 50%
b) $Hb^S Hb^S$ 25%
c) 0: the genotype is not affected by the blood transfusion.
3. All adult F_1 will be green, albinos die.
4. Genotypic ratio: 1 homozygous dominant: 1 heterozygote
Phenotypic ratio: All F_1 will have Huntington's chorea.

E. Sex-Linked Genes

1. All girls are normal, but carriers.
All boys are color-blind.
2. Two-thirds female: one-third male.
3. A color-blind girl could only be the result of a union of (a) a mother with normal vision but a carrier ($X^O X$), with a colorblind male ($X^O Y$); or (b) a spontaneous mutation of the X chromosome handed down by the father. The smart money goes for (a).
4. One normal male: one bent female.
5. 1/4 tortoise female; 1/4 black female; 1/4 yellow male; 1/4 black male. No.
6. Two normal females: 1 normal male (male with lethal dies).

F. Recombination

1. The P_0 cross is $BBVV \times bbvv$.
The F_1 test cross is: $BbVv \times bbvv$.
If unlinked, the F_2 phenotypic ratio should be 1:1:1:1. It is not, so the two genes are on the same chromosome.

The two smallest F₂ phenotypic classes are recombinants. Since map distance is defined as $\frac{\# \text{Recombinants}}{\text{total}} \times 100$, $\frac{111}{600} \times 100 = 18\%$.

2. a) A B C b) not with this information alone c) furthest away from A (*i.e.*, A B C D)
3. The genes are linked; otherwise the phenotypic ratio would be 1:1:1:1. Dpy and Unc are the smallest, and hence recombinant, classes. Therefore, $\frac{200}{1000} \times 100 = 20\%$ or 20 map units.
4. The genes are not linked.

G. Pedigree Analyses

1. This condition is not autosomal dominant or sex-linked dominant because F₁ #7 is afflicted and her parents are normal.

This condition is not sex-linked recessive because a cross between parents 1 and 2 would give all normal heterozygous daughters and all afflicted sons. (Note: F₁ #2 is not deaf).

Deafness appears to be passed on in accordance with expectations for inheritance of a recessive autosomal allele.

2. a. dominant
b. recessive, probably sex-linked (male afflicted, female carrier)
c. recessive
d. dominant