

Genetic Problems

THE FOLLOWING INVOLVE ONE-GENE CROSSES

Mendel observed seven traits in pea plants that exhibited complete dominance (the heterozygote expresses only the dominant allele, the recessive allele is masked.) For instance, he found that red flowers (R) were dominant over white flowers (r) by conducting the following crosses.

1. He crossed a homozygous red-flowered plant with a homozygous white-flowered plant. He called this the parental generation (P). The progeny of this cross were all red, therefore, the allele for red completely masked the one for white.
2. Next he crossed the red, heterozygous F1's. He called this a monohybrid cross. (One gene, heterozygous in both parents). Determine genotypic and phenotypic ratios for this cross.
 $Rr \times Rr$
3. Because the following cross will often reveal whether an organism exhibiting a dominant trait is homozygous or heterozygous it is called a back (or test) cross.
 $Rr \times rr$
Determine the genotypic and phenotypic ratios for this cross.
4. In *Drosophila*, gray body color is dominant over black body color. By crossing a heterozygous gray-bodied fly with a black-bodied fly, 100 offspring resulted. How many would be expected to have black bodies?
5. Albinism, the lack of pigment, occurs commonly in animals and is always recessive to normal pigmentation. Ten brown and eight albino mice were born to parents which were likewise brown and albino. What are the genotypes of both parents?
6. The ability to roll one's tongue into a 'U' is determined by a dominant allele (R). Two tongue rollers have a child who cannot roll his tongue. (a) What are the genotypes of the parents and their son? (b) What is the probability that their next child will be a non-tongue roller?
7. When a long-tailed cat was mated to a tailless cat, all of their kittens had short tails. When two short-tailed cats were mated, their litter contained three kittens without tails, two with long tails and six with short tails. Explain this pattern of inheritance and determine the genotypes for tailless, long-tailed and short-tailed cats.
8. In dogs, wire hair is due to a dominant factor, smooth hair to its recessive allele. Two wire-haired dogs produce a male pup which is wire haired. To find out most quickly whether he carries the factor for smooth hair, he should be mated to what kind of female? What term is applied to a cross of this type? the function of which is the determination of an unknown genotype).

9. In man, normal pigmentation is due to a dominant factor (C), albinism to its recessive allele (c). A normal man marries an albino woman. Their first child is an albino. What are the genotypes of these three persons? If they have a second child, what is the probability that it will also be an albino?
10. An albino man marries a normally pigmented woman. They have nine children, all normally pigmented. What are the genotypes of the parents and of the children? If they had but two children could we have been so definite as to the genotype of the mother? Explain.

THE FOLLOWING PROBLEMS INVOLVE TWO GENE CROSSES

When doing these, **be sure that each haploid gamete contains one allele for each trait.**

11. Brown hair (B) is dominant over blond (b) and curly (H) is dominant over straight (h). Determine the **genotypic and phenotypic** ratios for the following crosses.
- BBHH x bbhh (Parental cross)
 - BBhh x bbHH
 - BbHh x BbHh (F1 dihybrid cross)
 - BbHh x bbhh (Back cross)
12. In peas, tall (T) is dominant over short, and yellow seeds (Y) is dominant over green seeds.
- What will be the genotypes that result from the crossing of a homozygous tall, yellow-seeded plant with a short, green-seeded plant?
 - When these F1's are crossed with each other, many plants result, ninety of which are tall and yellow-seeded. Assuming the ideal ratio, how many would be expected to be short and green-seeded?
13. In rabbits black fur is dominant over white, and black eyes are dominant over pink. A white, pink-eyed female had a litter consisting of one rabbit with black fur and pink eyes, one with black fur and black eyes, one with white fur and pink eyes, and one with white fur and black eyes. What is the genotype of the father of this litter?
14. In cattle, long tails (T) are dominant over short tails (t). A cross between cattle with a red coat (R) and those with a white coat (r) result in offspring with roan (Rr) coats. A long tailed roan bull is mated to three cows. With cow A, which is short tailed and white, a short tailed roan calf is produced. With cow B, which is short tailed and roan, a long tailed red calf is produced. With cow C, which is long tailed and red, a short tailed red calf is produced. What are the genotypes of all of these individuals?

15. Shorthorn cattle may be red, white, or roan in color. The roan is an intermediate coloration due to a mixture of red and white hairs, and is the result of incomplete dominance. A breeder of shorthorn cattle has cows which are white, and a bull which is roan. What proportion of the calves produced in this herd will be white? roan? red? Let R designate the white allele of the gene for coat color, and r designate the red allele.
- Which of the calves would be homozygous? Which would be heterozygous?
 - Starting with a roan bull and white cows, could you eventually establish a true-breeding red here? How?
16. In horses, black is dependent upon a dominant factor (B) and chestnut upon its recessive allele (b). The trotting gait is due to a dominant factor T, the pacing gait to its recessive allele (t). If a homozygous black pacer is mated to a homozygous chestnut trotter, what will be the appearance of the F1 generation?
17. If two F1 individuals from the preceding problem were mated, what kinds of offspring would they have, and in what proportions? If an F1 male were mated to a homozygous female black pacer, what kinds of offspring would be produced and in what proportions?
18. In rabbits, black is due to a dominant factor (B), brown to its recessive allele (b). Short hair is due to a dominant factor (S), and long hair to its recessive allele (s). In a cross between a homozygous black short haired male and a homozygous brown long-haired female, what would be the genetic constitution and the appearance of the F1 generation? The F2 generation?
19. Suppose that you should back cross the F1 female rabbits in problem 18 to their black short-haired male father, what would be the appearance of the offspring? If instead you backcross the F1 males to their brown-long-haired mother, what would be the appearance of the offspring? Which one of these backcrosses could be considered to be a test cross?
20. Suppose that you have a homozygous black short-haired male rabbit and a brown longhaired female rabbit, and wish to develop a homozygous strain of black long-haired rabbits from them. Outline the breeding procedure necessary to establish such a strain.
21. For the following cross, what fraction of the offspring would be expected to exhibit all five dominant traits (ABCDE)? Hint: Separately determine the phenotypic ratio for each gene cross. Express it as a fraction, then multiply these fractions.

$$AaBbCcddEe \times AabbCCDdEE$$

THE FOLLOWING PROBLEMS DEAL WITH LINKED GENES (alleles that are located on the same chromosome.) A bar is placed above the linked genes indicating that they are physically attached.

22.. In *Drosophila*, the alleles for body color and wing shape are on the same chromosome some. Gray body (B) is dominant over black body (b) and normal wings (W) are dominant over stumpy wings (w). Disregarding crossover, determine the expected phenotypic ratios resulting from the following crosses:

- a. $BW \overline{BW} \times bw \overline{bw}$
- b. $BW \overline{bw} \times BW \overline{bw}$
- c. $BW\overline{bw} \times bw\overline{bw}$
- d. $B\overline{w} \overline{Bw} \times b\overline{W} \overline{bW}$

23. Mapping chromosomes, i.e. determining the order of alleles on a chromosome, is accomplished by examining crossover frequencies for linked genes. In *Drosophila*, information gotten by many crosses revealed that alleles A,B,C and D were on the same chromosome since they were usually inherited together. By setting up the following cross:

$ABCD \overline{abcd} \times \overline{abcd} \overline{abcd}$

Crossover frequencies were examined. Without crossover, half of the offspring would show all four dominant traits and half would show all four recessive traits. But this is not what happened. Some offspring had dominant A and recessive b, or recessive a and dominant B. Both of these were counted as crossovers between A and B since AB or ab had been separated. **The greater the distance between two linked alleles, the greater will be their crossover frequency, and alleles which are next to each other on the same chromosome will rarely be separated.**

The following are crossover frequencies for the above cross. From these frequencies , determine the order of alleles on the chromosome. **Remember, the farther apart the alleles, the more frequently crossover will occur between them.**

Alleles	Crossover Frequency
A & B	25%
A & C .	15%
A & D	15%
B & C	10%
B & D	40%
C & D	30%

24. In fruit flies there is a dominant allele for gray body color and a dominant allele for normal wings. The recessive allele for each is black body and vestigial wings. Flies homozygous for gray bodies and normal wings were crossed with black bodies vestigial winged flies. The F₁ offspring were then test crossed with the following results:

gray bodies, normal wings	236
black bodies, vestigial wings	253
gray bodies, vestigial wings	50
black bodies, normal wings	61

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

25. The recombination frequencies between A and B is 40%, between C and D is 10%: between C and A is 20%: and between D and B is 10%. What is the sequence of the genes on the chromosomes and in what order?

26. The following is another way you may see a map. For the following genes that are linked, determine their sequence.

d	dp	net	J	ed	ft	cl	ho
d-	18	31	10	20	19	14.5	27
dp	-	13	28	2	1	3.5	9
net		-	41	11	12	16.5	4
J			-	30	29	24.5	37
ed				-	1	5.5	7
ft					-	4.5	8
cl						-	12.5
ho							-

THE FOLLOWING PROBLEMS DEAL WITH GENE INTERACTIONS WHERE TWO OR MORE GENES PAIRS INTERACT TO EFFECT ONE TRAIT.

29. In mice the allele that produces pigment (C) is epistatic to the one that distributes the pigment in stripes (B). If an animal carries a dominant C but two recessive bb, pigment will be distributed evenly and the mouse will be black. If it carries two recessive cc, no pigment will be made and it will be white. If it carries a dominant C and a dominant B. it will be striped. The following cross was made:

Phenotypes	Black x	White
Genotypes	CCbb x	ccBB
Gametes	Cb	cB

All of the offspring were **striped** and their genotypes were:

CcBb

Cross two of these striped mice and determine the phenotypic ratios for the next generation.

30. An example of **complementary genes** is found in sweet pea flowers. One gene, B, produces the raw material for a purple pigment (not the pigment itself) and another gene, P, produces an enzyme that converts this raw material into purple pigment. Therefore, a plant must have a dominant B and a dominant P in order to be purple. All other combinations are white.

Parental cross: BBPP x bbpp
(purple) (white)

F1 generation BbPp
(purple)

Diagram an F1 dihybrid cross and determine the phenotypic ratio of the F2 generation.

31. Another type of genic interaction is called **collaboration**. In this case, two genes interact to produce four different phenotypes. An example of collaboration occurs in the feather colors of budgies (what you call parakeets).

Genotype	Phenotype
B_yy	Blue
bb Y_	Yellow
B_ Y_	Green
bb yy	White

(A dash indicates that the second allele can be either dominant or recessive.) A blue budgie having the genotype Bbyy is mated to a yellow bird having the genotype bbYy. What is the phenotypic ratio of their offspring?

32.. **Multiple genes or polygenes** are responsible for such traits as height or skin color. An individual has many genes that contribute to the same trait. An example of multiple genes or polygenes is found in wheat. The seeds range in color from white to light to medium to dark to red (which is the darkest.) Each dominant allele separately adds to the phenotype in the following manner:

Genotype	Phenotype
aabb	white
Aabb	light
aaBb	light
AAbb	medium
AaBb	medium
aaBB	medium
AABB	dark
AaBB	dark
AABB	red

Determine the phenotypic ratio for the following cross:

AaBb x AaBb

Problems 33 and 34 involve **multiple alleles**. In this case, more than two alleles exist in the population, though each individual has only two of these alleles. ABO blood types are an example of multiple alleles. Within the population there are three alleles, A, B, and O. A and B are codominant and O is recessive to both. The following is the relationship between genotype and phenotype:

Genotype	Phenotype
AA	type A
AO	type A
BB	type B
BO	type B
AB	type AB
OO	type O

33. a. Cross a heterozygous A with a heterozygous B and determine the possible blood type of their children.

b. In a court of law, a type A mother claims that a type B man is the father of her type O child. Is this possible? What if this man's parents were both type AB?

34. Another example of multiple allele exists in Labrador retrievers. Three alleles exist in the population: one codes for black C^B , one for chocolate C^C , and one for golden C^g . Black is dominant over chocolate, and both are dominant over golden. Therefore, a golden retriever must have the genotype: C^gC^g .

(a) Determine the phenotypes of the parents of the following cross

(b) Determine the genotypic and phenotypic ratios for the offspring.

$$C^B C^g \times C^C C^g$$

THE FOLLOWING PROBLEMS INVOLVE SEX LINKAGE. A sex-linked gene is one that is physically located on the X chromosome and is **recessive to the** normal condition. Because a female has two X's and males only one, the patterns of inheritance are different from those of autosomal genes. **ALWAYS USE X's AND Y's** when dealing with sex-linked traits. In humans colored blindness and hemophilia are sex-linked. In *Drosophila*, the genes for eye color are sex-linked (located on the X chromosome). Red eyes (R) are dominant to white eyes (r). In setting up crosses for this sex-linked trait, use the following notation:

Genotype	Phenotype
$X^R X^R$	Normal female (red eyes)
$X^R X^r$	Carrier female (red eyes) (not exhibiting recessive trait)
$X^r X^r$	Female showing trait (white eyes)
$X^R Y$	Normal male (red eyes)
$X^r Y$	Male showing trait (white eyes)

35. How could one determine whether a sex-linked trait was dominant or recessive? Which of the above genotypes would reveal this?

36. Red-green color blindness is a sex-linked recessive. A normal male marries a color-blind woman. What would be the chance that their sons would be colorblind? Their daughters?
37. In human beings the bleeder's disease, hemophilia, is inherited in the same way as white eyes in *Drosophila*. This condition is due to an X-linked recessive gene. Until very recently no authenticated cases of hemophilia in females were recognized. If one should occur, what prediction could we make with respect to the presence or absence of hemophilia in the mother and father of the hemophilia girl? What is the probability that her brother might be affected? Would it be possible for a son to inherit hemophilia from his father? How does hemophilia son inherit this condition?

THE FOLLOWING PROBLEMS CAN EXHIBIT ANY PHENOMENON USE APPROPRIATE LETTERS, SHOW WORK AND EXPLAIN YOUR ANSWERS.

38. Curly hair is dominant over straight hair and color blindness is a sex-linked recessive. A curly-haired man whose mother was color blind and whose father had straight hair is engaged to a woman whose color blind mother had straight hair, and whose normal visioned father had straight hair. If they marry and have a family what are their chances of having: (a) a curly-haired, normal visioned child? (b) a straight-haired color blind child? (c) a curly-haired, color blind daughter?
39. Aniridia is a type of blindness that is due to a dominant allele (A). Hemophilia is a disease in which the blood does not clot properly and it results from a sex linked recessive allele. A non-hemophiliac man who is blind from aniridia but whose mother was not blind marries a non-hemophiliac woman who is not blind but whose father was afflicted with hemophilia. If four sons are born to this couple, what different combinations of traits might they exhibit in regard to aniridia and hemophilia?
40. A male gamete of corn contains 10 chromosomes.
- How many of each type of chromosome would be found in a cell of a leaf of a corn plant?
 - How many total chromosomes would be found in the leaf cell mentioned above?
41. How essentially does the process of meiosis differ from the process of mitosis? You should consider both the important difference in the behavior of the chromosomes during the prophase and metaphase of mitosis and the first prophase and metaphase of meiosis, and the result of these differences as reflected in the chromosome numbers of the daughter cells resulting from mitosis and meiosis. How may the behavior of the homologous chromosomes during the first anaphase of meiosis be correlated with Mendel's Law of Segregation as it applies to genes? How may the behavior of different pairs of homologous chromosomes during the first meiotic anaphase be correlated with Mendel's Law of Independent Assortment as it applies to genes?

42. In tomatoes, red fruit color is dependent upon a dominant factor (R), yellow is dependent upon its recessive allele (r); tallness is due to a dominant factor (T), dwarfness to its recessive allele (t). The Golden Beauty variety has yellow fruit and is tall. The Dwarf Giant is dwarf and with red fruit. Using these two varieties to start with, could you eventually obtain a homozygous variety which was tall with red fruit? Could you obtain a homozygous variety which was tall with red fruit? Could you obtain a homozygous variety with red fruit and is all? Could you obtain a homozygous variety which was dwarf with yellow fruit? Which would be more readily obtained? Outline the procedure in each case.
- 43.. White fruit of summer squashes is due to a dominant factor (W), and colored fruit is due to its recessive allele (w). Disc-shaped fruit is due to a dominant factor (D), sphere-shaped fruit to its recessive allele (d). How many different genotypes may squash plants have in regard to color and shape of fruit? How many phenotypes result from these genotypes? How many different homozygous genotypes are possible?
44. In poultry, black color is due to a dominant factor (B), red to its recessive allele (b). Crested head is due to a dominant factor (C), plain head to its recessive allele (c). A red crested bird is mated to a black plain female. They produce offspring, half of which are black, crested, and half red, crested. What are the genotypes of the parents?
45. In garden phlox, white flowers are due to a dominant factor (W), cream to its recessive allele (w). Salver-shaped flowers are due to a dominant factor (S), funnel-shaped flowers to its recessive allele (s). A plant producing cream, salver-shaped flowers is crossed with one producing white, funnel-shaped flowers. Of the offspring, one quarter produced white, salver-shaped flowers, one-quarter produced cream, salver-shaped flowers, one-quarter produced white, funnel shaped flowers, and one-quarter produced cream, funnel-shaped flowers.
46. A plant producing white salver-shaped flowers is crossed with one producing cream, funnel-shaped flowers. What were the genotypes of the parents if out of 76 offspring 37 produce white salver shaped flowers and 39 cream, salver shaped flowers.
47. A rough, long-haired, black male guinea pig is mated to a rough, short-haired, white female. Rough hair (R) is dominant to smooth hair (r), short hair (S) is dominant to long (s), and black hair (B) is dominant to white hair (b). After they have produced several litters, their offspring have been found to be as follows: 15 rough, short-haired black; 13 rough, long-haired, black; 4 smooth, short-haired, black; and 5 smooth, long-haired, black. What were the genotypes of the parents?
48. In cocker spaniels, black is due to a dominant factor (B), red to its recessive allele (b). Solid color is dependent upon a dominant factor (S) white spotting upon its recessive allele (s). A solid red male is mated to a black and white female. They have 5 puppies as follows: one black, one red, one black and white, and two red and white. What were the genotypes of the parents?

49. In wheat, red kernel color is dependent upon the presence of two dominant factors, (R) and (B), white kernel color upon the presence of both recessives in the homozygous state. Other combinations result in brown. Two brown varieties, rrBB and RRbb are crossed. What is the appearance of the F₁ and F₂? (NOTE: This problem illustrates an important fact: The phenotype of an individual with respect to a single characteristic is more often than not the product of the interaction of two or more pairs of genes.)
50. If you had a large number of F₂ kernels from the preceding cross, how would you go about developing a homozygous red variety? Remember that wheat is normally self-fertilized.
51. Congenital deafness in man is due to the homozygous condition of either or both of the recessive factors, (d) and (e). Both dominant factors, (D) and (E), are necessary for normal hearing. A deaf man marries a deaf woman and all of the seven children have normal hearing. What are the probable genotypes of the parents and children?
- 52..In *Drosophila* (the fruit fly), the wild type is red. A few flies, however, are found which possess white eyes. White eyes have been demonstrated to be due to an X-linked recessive gene. If after crossing two flies one finds that there are 48 red-eyed females, 21 red-eyed males, and 20 white eyed males in the progeny, what must have been the genotypes of the parents? Let (B) = red eyes, and (b) - white eyes.
53. Patented hybrid roses when received by the gardener often include a notice that prohibits self- pollination and distribution of the resultant seed by the home gardener or retailer. The hybrid, which arose from crossing two other parent varieties, is likely to be highly heterozygous. Can you explain on a genetic basis why distribution of seed obtained from self pollination is prohibited? How are such hybrid varieties propagated in the first place from a single plant in such a manner that the new individuals will be duplicates of the original?
54. In cats, short hair is dominant to long hair;the gene is autosomal, An allele B^I, of another gene is sex linked and produces a yellow coat color; the allele B² produces black coat; and the heterozygous mate B¹/B² produces a tortoise shell (calico) color. If a long haired black male is mated with a tortoise shelled female homozygous for short hair, what type of kittens would they produce in the F₁? If the F₁ cats were allowed to mate freely, what are the chances of obtaining a yellow haired male?
55. The following shows three generations of a pedigree of deafness in a family. Black circles indicate female deafness and black squares indicate male deafness. State whether the conditions of deafness in this family are inherited as:
- dominant autosomal
 - recessive autosomal
 - sex-linked dominant
 - sex-linked recessive.
 - a holandric characteristic