Practice Problems for Mendelian Genetics

1. A phenotypic ratio of 3:1 in the offspring of a mating of two organisms heterozygous for a single trait is expected when:

A. the alleles segregate during meiosis.

- B. each allele contains two mutations.
- C. the alleles are identical.

D. the alleles are incompletely dominant.

E. only recessive traits are scored.

Mendel first proposed that alleles segregate from one another during the formation of gametes.

2. In pea plants, spherical seeds (S) are dominant to dented seeds (s). In a genetic cross of two plants that are heterozygous for the seed shape trait, what fraction of the offspring should have spherical seeds?

A. None

B. 1/4

C. 1/2

D. 3/4

E. All

Setting up a Punnett square

The figure above represents a monohybrid cross of F1-hybrid plants. Both parent plants are heterozygous (Ss) for an allele that determines seed shape. Presence of the dominant allele (S) in homozygous (SS) or heterozygous (Ss) plants results in spherical seeds. Homozygous recessive (ss) plants have dented seeds.

To solve problem, you'll need to set up a Punnett square. This tutorial will walk you through that process.

Set up a 2 by 2 Punnett square.	
Write the alleles for parent 1 on the left side of the Punnett square.	s
Each gamete will have one of the two alleles of the parent. In this particular cross, half of the gametes will have the dominant (S) allele, and half will have the	s





recessive (s) allele. We will use blue and brown to keep track of the alleles of each parent.	
Write the alleles from parent 2 above the Punnett square. For this heterozygous parent (Ss), half of the gametes will have the dominant (S) allele, and half will have the recessive (s) allele.	S S S S
Fill the squares for parent 1. Fill each square with the allele from Parent 1 that lines up with the row.	S S S S S s S S
Fill the squares for parent 2. Fill each square with the allele from Parent 2 that lines up with the column.	S S S S S S S S S S S

Interpreting the results of a Punnett square

We now have the information for predicting the outcome of the cross. The genotypes in the four boxes of the Punnett square are each equally likely to occur among the offspring of this cross. We may now tabulate the results.

Genotypes that resulted from this monohybrid cross (Ss x Ss)



Phenotypes that resulted from this monohybrid cross (Ss x Ss)



3. In Mendel's "Experiment 1," true-breeding pea plants with spherical seeds were crossed with true-breeding plants with dented seeds. (Spherical seeds are the dominant characteristic.) Mendel collected the seeds from this cross, grew F1-generation plants, let them self-pollinate to form a second generation, and analyzed the seeds of the resulting F2 generation. The results that he obtained, and that you would predict for this experiment are:

Λ 1/2 the E1 and 2/4 of the E2 generation goods were spheric							
$A_{11/2}$ the F1 and $3/4$ of the F2 generation seeds were spherical	neration seeds were spheric	F2 ş	of the	and 3/4	F1	/2 the	A.

B. 1/2 the F1 and 1/4 of the F2 generation seeds were dented.

C. All of the F1 and F2 generation seeds were spherical.

D. 3/4 of the F1 and 9/16 of the F2 generation seeds were spherical.

E. All the F1 and 3/4 of the F2 generation seeds were spherical

Tutorial

F1-generation plants

Mendel crossed SS (spherical seeds) with ss (dented seeds.)

All of the gametes of the spherical seeded parent have the S (dominant) allele and all of the gametes of the dented seeded parent have the s (recessive) allele. All of the F1 generation plants will have the genotype of Ss (heterozygous), and all will be spherical seeded.

F1 generation



F2-generation plants

Mendel let the F1-generation plants self-pollinate to form a second generation and he analyzed the seeds of the resulting F2 generation.

F2 generation



5. A genetic cross between two F1-hybrid pea plants for spherical seeds will yield what percent spherical-seeded plants in the F2 generation? (Recall, spherical-shaped seeds are dominant over dented seeds.)

A. 100%

B. 75%

C. 50%

D. 25%

E. 0%

Tutorial

Crossing two heterozygotes

The parent plants are heterozygous for an allele that determines seed shape. We can use a Punnett square to predict the phenotypes of their offspring.

The F1-hybrid plants have the dominant (S), spherical seed phenotype. In the Punnett square, we see that one out of four possible combinations of F2-generation plants has the homozygous recessive genotype (ss).



6. A genetic cross between two F1-hybrid pea plants having yellow seeds will yield what percent green-seeded plants in the F2 generation? Yellow seeds are dominant to green.

A. 0%

B. 25%

C. 50%

D. 75%

E. 100%

7. When true-breeding tall stem pea plants are crossed with true-breeding short stem pea plants, all of the _____ plants, and 3/4 of the _____ plants had tall stems. Therefore, tall stems are dominant.

A. F1, F2.

B. G1, G2.

C. parental, F2.

D. F2, parental.

E. P1, P2

8.

To identify the genotype of yellow-seeded pea plants as either homozygous dominant (YY) or heterozygous (Yy), you could do a test cross with plants of genotype _____.



A test cross

A. y

B. Y

C. yy

A cross with the homozygous recessive (yy) is a test cross. If the parent of unknown genotype is heterozygous (Yy), half of the offspring will have the recessive trait. The unknown genotype could also be determined by a cross with a known heterozygote (Yy).

D. YY

E. Yy

8. A test cross is used to determine if the genotype of a plant with the dominant phenotype is homozygous or heterozygous. If the unknown is homozygous, all of the offspring of the test cross

have the ______ phenotype. If the unknown is heterozygous, half of the offspring will have the ______ phenotype.

- A. dominant, incompletely dominant
- B. recessive, dominant
- C. dominant, epistatic
- **D.** codominant, complimentary
- **E.** dominant, recessive

The test cross was invented by Mendel to determine the genotype of plants displaying the dominant phenotype.

Test cross with yy

In the test cross invented by Mendel, the plant with the dominant phenotype is crossed with a plant that is homozygous for the recessive trait. If the unknown is homozygous, all offspring will have the dominant phenotype. If the unknown is heterozygous, half of the offspring will have the recessive phenotype.



9. In Mendel's experiments, if the gene for tall (T) plants was incompletely dominant over the gene for short (t) plants, what would be the result of crossing two Tt plants?

A. 1/4 would be tall; 1/2 intermediate height; 1/4 short The heterozygous offspring (Tt) would be of intermediate height.

B. 1/2 would be tall; 1/4 intermediate height; 1/4 short.

C. 1/4 would be tall; 1/4 intermediate height; 1/2 short.

D. All the offspring would be tall.

E. All the offspring would be intermediate.

A cross of two F1 hybrids, heterozygous for a single trait that displays incomplete dominance is predicted to give a 1:2:1 ratio among both the genotypes and phenotypes of the offspring. 1/4 will have the dominant phenotype (tall, TT), 1/2 will have the intermediate phenotype (Tt) resembling the parents of this cross, and 1/4 will have the recessive phenotype (short, tt.) When incomplete dominance occurs, it is not necessary to do a test cross to identify the heterozygotes.





10. Human blood type is determined by codominant alleles. There are three different alleles, known as I^A , I^B , and i. The I^A and I^B alleles are codominant, and the i allele is recessive.

The possible human phenotypes for blood group are type A, type B, type AB, and type O. Type A and B individuals can be either homozygous ($I^A I^A$ or $I^B I^B$, respectively), or heterozygous ($I^A i$ or $I^B i$, respectively).

A woman with type A blood and a man with type B blood could potentially have offspring with which of the following blood types?

A. type A

B. type B

C. type AB

D. type O

E. all of the above

But if the man was type O rather than type B, offspring of type B and type AB would not be possible.

Tutorial

Blood type and genotype

Phenotype (Blood type)	Genotype
Type A	I ^A I ^A or I ^A i
Туре В	I ^B I ^B or I ^B i
Type AB	$\mathbf{I}^{A}\mathbf{I}^{B}$
Type O	11

The relationship between blood type (phenotype) and genotype is shown in the table to the left. The mother (blood type A) and father (blood type B) could be either homozygous or heterozygous.

Type A and type B cross

Mother (Type A)	X Father (Type B)
$\mathbf{I}^{A}\mathbf{I}^{A}$	I ^B i
I ^A I ^A	I ^B I ^B
I ^A i	I ^B I ^B
I ^A i	I ^B i

Four different genetic crosses are possible. All four crosses must be considered to determine all potential offspring. However, one cross (I^Ai mother x I^Bi father) is most informative.

11. What are the possible blood types of the offspring of a cross between individuals that are type AB and type O? (Hint: blood type O is recessive)

A. AB or O

B. A, B, or O

C. A or B

A cross between individuals that are of genotype $I^A I^B x$ ii can yield offspring that are either I^A i or I^B i. Their blood type will be A or B.

D. A, B, AB, or O

E. A, B, or AB

Tutorial

In this problem (in contrast to problem 11), there is no uncertainty about the genotype of either parent. A parent of blood type AB has the codominant I^A and I^B alleles. A parent of blood type O is homozygous recessive for the i allele.

The Punnett square for their offspring is shown to the right. The genotypes of their offspring could be either I^Ai or I^Bi. Their children could be in blood groups A or B, but not AB or O.



For more information on blood types inheritance go to our <u>Blood</u> <u>Types Tutorial</u>within the Human Biology Section of The Biology Project.

Half of the children predicted to be **Type A**, and half **Type B**.

Dihybrid Cross Problem Set

A dihybrid cross involves a study of inheritance patterns for organisms differing in two traits. Mendel invented the dihybrid cross to determine if different traits of pea plants, such as flower color and seed shape, were inherited independently. Our objective is to understand the principles that govern inheritance of different traits in a dihybrid cross that led Mendel to propose that alleles of different genes are assorted independently of one another during the formation of gametes.

1. A pea plant is heterozygous for both seed shape and seed color. S is the allele for the dominant, spherical shape characteristic; s is the allele for the recessive, dented shape characteristic. Y is the allele for the dominant, yellow color characteristic; y is the allele for the recessive, green color characteristic. What will be the distribution of these two alleles in this plant's gametes?

- A. 50% of gametes are Sy; 50% of gametes are sY
- **B.** 25% of gametes are SY; 25% of gametes are Sy; 25% of gametes are sY; 25% of gametes are sy.

Alleles of different genes are assorted independently of each other during the formation of gametes.

- C. 50% of gametes are sy; 50% of gametes are SY
- **D.** 100% of the gametes are SsYy
- E. 50% of gametes are SsYy; 50% of gametes are SSYY.

Tutorial

Assortment of Ss alleles

The gametes from the SsYy parent will receive one of the two alleles Ss.

Half will receive the dominant S allele, and half the recessive s allele.



Assortment of Yy alleles

The gametes from the SsYy parent will also receive one of the two alleles Yy.

Half will receive the dominant Y allele, and half the recessive y allele.

Possible combinations of alleles in gametes of plants heterozygous for two traits.

Since alleles of different traits segregate independently during gamete formation, there is the same probability that the Y (or y) allele will segregate with the S allele as with the s allele.

Thus all four combinations of gametes (SY, Sy, sY, sy) are equally probable.

2. Problem 2: When does a phenotype ratio of 9:3:3:1 occur?



A phenotype ratio of 9:3:3:1 in the offspring of a mating of two organisms heterozygous for two traits is expected when:

A. the genes reside on the same chromosome

B. each gene contains two mutations

C. the gene pairs assort independently during meiosis

The parental organisms have the same phenotype, but their offspring have 4 different phenotypes. The 9: 3: 3: 1 ratio can only occur if the two traits assort independently during meiosis.

D. only recessive traits are scored

E. none of the above.

Tutorial

A. the genes reside on the same chromosome

Genes on the same chromosome might be linked. If we assume linked genes, and that the heterozygotes are F1-hybrids from true breeding parents, the offspring would be predicted to occur in a 3:1 ratio of sperical, green- to dented, yellow-seeded plants.

B. each gene contains two mutations

Without information on the relationship between mutation and phenotype, this choice can be eliminated.

C. the gene pairs assort independently during meiosis

A phenotype ratio of 9:3:3:1 in the offspring means that all four possible combinations of the two different traits are obtained. The only way that new combinations of alleles can occur in the offspring that are absent in the heterozygous parents is if the alleles for different traits assort independently during gamete formation. As we will see in the tutorial for <u>Problem 3</u>, a 9:3:3:1 ratio is expected.



If only recessive traits were scored, we would only consider offspring with one phenotype: dented, green seeds. A 9:3:3:1 ratio phenotypes would be impossible.

3. Problem 3: A genetic cross yielding a 9:3:3:1 ratio of offspring.

Which of the following genetic crosses would be predicted to give a phenotypic ratio of 9:3:3:1?

A. SSYY x ssyy

All offspring would have genotype of SsYy and a phenotype dominant for both traits (spherical, yello-seeded plants.)

B. SsYY x SSYy

All offspring would have genotype of either SSYY, SSYY, SsYY, or SsYy, and a phenotype dominant for both traits (smooth, yellow-seeded plants.)

C. SsYy x SsYy

The dihybrid cross was invented by Mendel to discover the independent assortment of alleles during gamete formation.

D. SSyy x ssYY

All offspring would inherit dominant S allele from first parent and dominant Y allele from sedonc parent. All offspring would have genotype of SsYy and a phenotype dominant for both traits (spherical, yellow-seeded palnts.)

E. ssYY x ssyy

All offspring would have the genotype ssYy and a phenotype of dented, yellow-seeded plants.

Problem 4: Predicting gametes of an SsYy plant.

The gametes of a plant of genotype SsYy should have the genotypes:

A. Ss and Yy

B. SY and sy

C. SY, Sy, sY, and sy

Each gamete will receive either on S or s allele, and either a Y or y allele. All of S or s, and Y or y are possible.

D. Ss, Yy, SY and sy

E. SS, ss, YY, and yy

Assortment of alleles

The gametes will receive one of each pair (Ss and Yy) of alleles. All combinations of alleles will occur with equal probability (SY, Sy, sY, and sy) because alleles of different genes are assorted independently during gamete formation (meiosis.)

Each gamete has one seed shape (S=spherical or s=dented) and one color (Y=yellow or y=green) allele.

SY SY SY SY

Problem 5: A SsYy x ssyy test cross.

Which of the following genotypes would you not expect to find among the offspring of a SsYy x ssyy test cross:

A. ssyy

B. SsYy

C. Ssyy

D. ssYy

E. SsYY

Offspring could not be homozygous for the dominant yellow seed color (YY), because one recessive y allele must be inhereited from the ssyy parent.

Problem 6: Offspring of a SsYy x ssyy test cross.

The expected phenotypic ratio of the progeny of a SsYy x ssyy test cross is:

A. 9:3:3:1.

B. 3:1.

C. 1:1:1:1.

SsYy, ssYy, Ssyy, ssyy are predicted to occur in a ratio of 1:1:1:1.

D. 1:2:1.

E. 3:1:1:3.

In a dihybrid cross, AaBb x AaBb, what fraction of the offspring will be homozygous for both recessive traits?

A. 1/16

1/4 of the gametes of each parent will be ab. The fraction of the offspring homozygous for both recessive traits will be 1/4 times 1/4, or 1/16.

B. 1	/8
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C. 3/16

D. 1/4

E. 3/4

Tutorial

Predicting the genotype of offspring

There are four possible combinations of gametes for the AaBb parent.

Half of the gametes get a dominant A and a dominant B allele; the other half of the gametes get a recessive a and a recessive b allele.

Both parents produce 25% each of AB, Ab, aB, and ab.

(Review problem #3's tutorial if necessary).

Possible gametes for each AaBb parent

Since each parent has four different combinations of alleles in the gametes, there are sixteen possible combinations for this cross. Therefore we use a 4 square by 4 square Punnett Square.





Alleles from both parents

Now we can predict the outcome of the genetic cross of AaBb x AaBb.

To determine the fraction of the offspring homozygous for both traits, first determine the genotype of an offspring homozygous for both traits. It would be aabb.

Offspring homozygous for both recessive traits

There is only one of 16 possible combinations with this genotype.

The predicted fraction is therefore 1/16.





Problem 8: Heterozygous offspring of a dihybrid cross.

Following a SsYy x SsYy cross, what fraction of the offspring are predicted to have a genotype that is heterozygous for both characteristics?

A. 1/16

B. 2/16

C. 3/16

D. 4/16

Four out of 16 possible combinations of alleles yield the SsYy genotype. They are:

SY and sy, sY and Sy, Sy and sY, SY and sy.

E. 9/16

Tutorial

Predicting the genotype of offspring

The solution for predicting the outcome of an SsYy x SsYy genetic cross was given in detail in the tutorials for problem 2 and problem 3. Review the answers to these problems if necessary.

These are the possible combinations of gametes for this cross.

Offspring heterozygous for both traits

There are 4 out of 16 possible combinations of gametes from an SsYy x SsYy cross with the genotype of SsYy. We would therefore predict that 4/16 (or 1/4) of the offspring of the cross would be heterozygous for both traits.





Problem 9: Homozygous offspring of a dihybrid cross, again.

Correct!

In a dihybrid cross, SsYy x SsYy, what fraction of the offspring will be homozygous for both traits?

A. 1/16

B. 1/8

C. 3/16

D. 1/4

There are four different genotypes that are homozygous for both traits. These are SSYY, SSyy, ssYY, and ssyy.

E. 3/4

Tutorial

Predicting the genotype of offspring

The solution for predicting the outcome of an SsYy x SsYy genetic cross was given in detail in the tutorials for problem 2_andproblem 3_. Review the answers to these problems if necessary.

These are the possible combinations of gametes for this cross.

Offspring homozygous for both traits

There are 4 out of 16 possible combinations of gametes from an SsYy x SsYy cross with the genotype of SsYy. We would therefore predict that 4/16 (or 1/4) of the offspring of the cross would be homozygous for both traits.

Note that there is a different phenotype for each of the 4 different combinations of alleles.

Problem 10: Exceptions to the 9:3:3:1 ratio of offspring?

If Mendel's crosses between tall, spherical-seeded plants and short, dented-seeded plants had produced many more than 1/16 short, dented-seeded plants in the F2 generation, he might have concluded that:

- A. the dented seed and short traits are unlinked.
- **B.** he would not have concluded any of the above.
- C. all traits in peas assort independently of each other.

D. the spherical seed and tall traits are linked.

Linked traits do not segregate independently during gamete formation. Mendel was probably very fortunate to have selected unlinked traits to study. Had he observed linked or partially-linked traits, it would have been more difficult to arrive at his theory that alleles of different genes assort independently during gamete formation.

E. all traits in peas are linked.

Tutorial





F1 offspring of unlinked alleles

In a dihybrid cross between plants with tall stems and spherical seeds (both dominant) and plants with short stems and dented seeds, all of the F1-hybrid plants would have both dominant characteristics.

The dihybrid cross is SSTT x sstt. All F1-hybrids would be SsTt.

F2 offspring for unlinked alleles

If the two traits are unlinked and the F1-plants are self-fertilized, in the F2 generation plants we expect the 9:3:3:1 ratio of offspring:

9/16 tall plants with spherical seeds 3/16 tall plants with dented seeds 3/16 short plants with spherical seeds 1/16 short plants with dented seeds

F1 offspring for linked alleles

An excess of parental genotypes in the F2 generation (such as more than 1/16 short plants with dented seeds) can occur if the loci for the two traits are on the same chromosome, and linked to each other on the same DNA molecule.

If two traits are closely linked on the same chromosome, the alleles for the linked genes do not segregate during the formation of gametes. The two dominant alleles are linked on one chromosome, and the two recessive alleles are linked on the other, homologous chromosome.

Sperical & tall ST st ST st

F2 offspring for linked alleles

We can use a Punnett Square to predict the outcome of this cross. The gametes of each parent will have the pairs of linked alleles, either ST or st. Since there are two combinations of alleles for each parent, we need a two square by two square Punnett Square. Fill out the Punnett Square to determine the genotype and phenotype for the offspring of a dihybrid cross when the traits are tightly linked.

Note that 3/4 of the offspring are predicted to have both dominant traits, and 1/4 are predicted to have both recessive traits. With unlinked traits, only 1/16 are predicted to have both recessive traits.

Problem 11: Incomplete dominance in a dihybrid cross.

In Mendel's experiments, the spherical seed character (SS) is completely dominant over the dented seed character (ss). If the characters for height were incompletely dominant, such that TT are tall, Tt are intermediate and tt are short, what would be the phenotypes resulting from crossing a spherical-seeded, short (SStt) plant to a dented-seeded, tall (ssTT) plant?

- A. All the progeny would be spherical-seeded and tall.
- **B.** 1/2 would be spherical-seeded and intermediate height; 1/2 would be spherical-seeded and tall.
- C. All the progeny would be spherical-seeded and short.
- **D.** You cannot predict the outcome.
- **E.** All the progeny would be spherical-seeded and intermediate height.

All of the offspring would have the genotype of SsTt. Mendel selected traits to study that did not display partial dominance. Could you predict the result of an SsTt x SsTt cross if one or both traits dispayed partial dominance? There would be 9 different phenotypes if both traits showed partial dominance.

Problem 13: AaBb dihybrid cross involving epistasis

Correct!

Two unlinked loci effect mouse hair color. **AA** or **Aa** mice are agouti. Mice with genotype **aa** are albino because all pigment production is blocked, regardless of the phenotype at the second locus. At the second locus, the **B**allele (agouti coat) is dominant to the **b** allele (black coat). What would be the result of a cross between two agouti mice of genotype AaBb?

- A. 4 agouti: 4 black: 8 albino
- B. 9 agouti: 3 black: 3 albino: 1 grey
- **C.** 9 agouti: 3 black: 4 albino

This is a variant of the normal 9:3:3:1 ratio for a normal dihybrid cross without epistasis.

D. 8 agouti: 4 black: 4 albino

Tutorial

A Punnet Square for the AaBb x AaBb cross is shown below. Rather than the 9:3:3:1 seqregation of phenotypes normally seen with an AaBb x AaBb dihybrid cross, the phenotypic ratio is 9:3:4. There are only three different phenotypes for hair color, agouti, black and albino. The individual with genotype recessive for both traits, i.e. aabb, has the same albino phenotype as the aaBB and aaBb individuals due to epistasis. The albino phenotype masks any phenotype that might be caused by the recessive homozygous, recessive bb genotype.

