

Bio 102 Practice Problems

Mendelian Genetics and Extensions

Short answer (show your work or thinking to get partial credit):

1. In peas, tall is dominant over dwarf. If a plant homozygous for tall is crossed with one homozygous for dwarf:
 - a. What will be the appearance (phenotype) of the F_1 plants?
 T =tall, t =dwarf
 F_1 : all tall (Tt)
 - b. What will be the phenotypes of the F_2 , and what fraction of the offspring will have each phenotype?
 F_2 will be $\frac{3}{4}$ tall (TT and Tt) and $\frac{1}{4}$ dwarf (tt)
 - c. What will be the phenotypes and fractions if an F_1 plant is crossed with its tall parent?
This cross is now $Tt \times TT$, so offspring are all tall but $\frac{1}{2}$ TT and $\frac{1}{2}$ Tt
 - d. What will be the phenotypes and fractions if an F_1 plant is crossed with its short parent?
This cross is $Tt \times tt$, so offspring are $\frac{1}{2}$ tall (Tt) and $\frac{1}{2}$ dwarf (tt)
2. A tall plant crossed with a dwarf one produces offspring, of which about half are tall and half are dwarf. What are the genotypes of the two parents?
We know that the dwarf parent is tt . If the tall parent were TT , all the offspring would be tall (Tt). So, the tall parent must be Tt , giving the cross $Tt \times tt$ and $\frac{1}{2}$ Tt and $\frac{1}{2}$ tt offspring.
3. If the tall parent in problem #3 is self-fertilized, what is the probability that the first offspring will be tall?
This cross is $Tt \times Tt$, so $\frac{3}{4}$ of the offspring should be tall. For any one offspring, the probability of being tall is therefore 3 in 4 or 75%.
4. In cattle, hornless (called "polled," represented by P) is dominant over horned (p). A polled bull is bred to three cows, A, B and C. Which cow A, which is horned, a polled calf is produced. With cow B, also horned, a horned calf is produced. With cow C, which is polled, a horned calf is produced.
 - a. What are the genotypes of the four parents (cows A, B, C and the bull)?
Cows A and B are horned, and horned is a recessive trait, so they must both be homozygous recessive, pp .
The bull is horned, but is capable of producing a horned calf (with cow B), so we know he can't be homozygous dominant. Therefore, he must be heterozygous, Pp .
Cow C is polled but is capable of producing a horned calf, so she also must have a p allele and be heterozygous, Pp .
So, Bull = Pp , Cow A = pp , Cow B = pp , Cow C = Pp
 - b. If a large number of offspring could be obtained from each mating, what would you expect the phenotypes of the offspring to be, and in what ratios?
Crosses A and B are the same: $Pp \times pp$, expect $\frac{1}{2}$ polled (Pp) and $\frac{1}{2}$ horned (pp)
Cross C: $Pp \times Pp$, expect $\frac{3}{4}$ polled (PP and Pp) and $\frac{1}{4}$ horned (pp)

5. Two black female mice are crossed with a brown male. In several litters, female #1 produced 9 black offspring and 7 browns. Female #2 produced 57 blacks.
- What can you determine about the inheritance of black and brown coat color from these data?
Black must be dominant, because not one of the 57 offspring of female #2 showed the brown trait, which is pretty unlikely if brown is dominant (even if the brown male is heterozygous).
 - What are the genotypes of the parents?
Female #2 is likely to be homozygous dominant (BB), so that when mated to a homozygous recessive male (bb), all the offspring are black (Bb).
Female #1 is likely to be heterozygous (Bb), so that when mated to a homozygous recessive male (bb), about half the offspring are black (Bb) and half are brown (bb).
6. In guinea pigs, rough coat (R) is dominant over smooth (r), and black coat (B) is dominant over white (b). If a pure-breeding rough black animal is crossed with a smooth white one:
- What will be the appearance of the F₁ progeny? The F₂?
The pure-breeding rough black animal is RRBB; the smooth white is rrbb.
The F₁ will therefore be all RrBb, all rough and black.
The F₂ cross is RrBb × RrBb, so in the offspring we expect:
9/16 rough and black (RRBB, RrBB, RRBb and RrBb)
3/16 rough and white (RRbb and Rrbb)
3/16 smooth and black (rrBB and rrBb)
1/16 smooth and white (rrbb)
 - What will be the offspring of a cross between the F₁ and the rough black parent?
This cross is RrBb × RRBB; every offspring will get at least one R and one B, so all will be rough and black (¼ RRBB, ¼ RrBB, ¼ RRBb, ¼ RrBb)
 - What will be the offspring of a cross between the F₁ and the smooth white parent?
This cross is RrBb × rrbb, so we expect:
¼ RrBb, rough black ¼ Rrbb, rough white
¼ rrBb, smooth black ¼ rrbb, smooth white
7. In the F₂ generation in problem #10, what proportion of the rough black offspring would be homozygous for both genes?
Just as there is only one way to get a double homozygous recessive (rb gamete meets rb gamete), there is only one way to get a double homozygous dominant (RB gamete meets RB gamete). So, only 1/16 of the total offspring will be homozygous dominant for both genes, or 1/9 of the rough black offspring.
8. A rough black guinea pig bred with a rough white one gives 28 rough black, 31 rough white, 11 smooth black and 10 smooth white. What are the genotypes of the parents?
Notice that there are 59 total rough and 21 total smooth, about 3:1; there are 39 total black and 41 total white, about 1:1.
Therefore, it is likely that for rough/smooth, the cross is Rr × Rr (¾ rough, ¼ smooth), and for black/white, it is Bb × bb (½ black, ½ white).
Putting these together, the parents are RrBb × Rrbb

9. Two rough black guinea pigs bred together have two offspring: one rough white and one smooth black. If these parents had more offspring, what phenotypes and proportions would you expect?

Since these animals have the dominant black and rough traits but can have white and smooth offspring, both must be heterozygous for both genes. Therefore, the cross is $RrBb \times RrBb$ and 9/16 rough black, 3/16 rough white, 3/16 smooth black and 1/16 smooth white are expected.

10. In humans, spotted skin (**S**) is dominant to non-spotted (**s**), and woolly hair (**W**) is dominant to non-woolly (**w**). List the genotypes and phenotypes of children to be expected from a marriage of a man whose genotype is **Ssww** and a woman whose genotype is **ssWw**.

$Ssww \times ssWw$ should give $\frac{1}{4}$ **SsWw** (spotted, woolly), $\frac{1}{4}$ **Ssww** (spotted, non-woolly), $\frac{1}{4}$ **ssWw** (non-spotted, woolly), and $\frac{1}{4}$ **ssww** (non-spotted, non-woolly)

11. Two red-eyed fruit flies are mated. They have the following offspring: 140 red-eyed flies and 48 flies with bright orange eyes.

- a. Which allele is dominant for the eye color gene: red or orange?

This looks very close to the expected results of a monohybrid cross between two heterozygous parents. Very nearly $\frac{3}{4}$ of the offspring are red-eyed and $\frac{1}{4}$ are orange-eyed. This suggests that the red-eyed flies have the dominant phenotype.

- b. What were the genotypes of the parents?

If **R** = red (dominant) and **r** = orange (recessive), then because there are orange-eyed offspring, we know both parents had to have a recessive orange allele to give. Since both of the parents are red, they must both have been heterozygous: **Rr**.

- c. Diagram the cross.

$Rr \times Rr$ $\frac{1}{4}$ **RR** and $\frac{1}{2}$ **Rr** = $\frac{3}{4}$ red; $\frac{1}{4}$ **rr** = $\frac{1}{4}$ orange

12. A fruit fly with long (normal) wings and red eyes is crossed with one that has short wings and brown eyes. Both of these parents are from pure-breeding lines. Two of their offspring are then crossed, and the F_2 generation is as follows:

45 brown, long
16 brown, short
139 red, long
51 red, short

- a. Based on this information, is there one gene that controls both eye color and wing length, or are these two traits due to two separate genes?

There must be two separate genes. If only one gene produced both long wings and red eyes, then we'd always find red and long together. This is not the case: the traits seem to follow the law of independent assortment, so there must be two separate genes.

- b. Which alleles are dominant?

This looks like a typical dihybrid cross (9:3:3:1). The red, long flies are very nearly 9/16 of the total, so red is dominant over brown and long is dominant over short.

- c. What were the genotypes of the parents?

The original parents were pure-breeding (homozygous), so if **R**=red and **r**=brown, and **L**=long and **l**=short, then the parents must have been **RRLL** (red, long) and **rrll** (brown, short).

- d. Would the results have been different if one parent were red, short and the other brown, long (assuming they were still pure-breeding?)

Now, the genotypes would have to be **RRll** (red, short) and **rrLL** (brown, long). BUT, the F_1 would still be heterozygous for both genes: **RrLl**! So the F_1 and F_2 crosses would still come out the same.

13. A pure-breeding pea plant with wrinkled yellow seeds is crossed with one that has round, green seeds. One of the F₁ offspring is testcrossed with a wrinkled, green plant. What fraction of their offspring should have round, yellow seeds?

Round and yellow are the dominant traits, so let R=round, r=wrinkled and Y=yellow, y=green. Now, the pure-breeding parents must have been rrYY (wrinkled, yellow) and RRyy (round green). Their F₁ offspring will be RrYy and have the round, green phenotype.

A testcross is a cross with a homozygous recessive, so the testcross is RrYy × rryy. The four gametes produced by the round, green plant will be RY, Ry, rY and ry; the only one that will lead to round, yellow offspring is RY (which when combined with an ry gamete from the tester will give RrYy). Therefore, ¼ of the offspring should be round and yellow.

14. If a pure-breeding purple-flowered pea plant is crossed with a pure-breeding white-flowered pea plant, all the offspring have purple flowers. Suppose two F₁ plants are crossed, and 2400 offspring are obtained. How many white-flowered plants will you expect?

Since all the F₁ have purple flowers, purple is dominant. If P=purple and p=white, then the parents are PP (which can produce only P gametes) and pp (which can produce only p gametes). Their offspring must all be Pp, heterozygous, and purple.

Now, when we cross Pp × Pp, each parent will make half P gametes and half p gametes. Using the Punnett square method, we can see that ¼ of the offspring should be pp (white):

	P	p
P	PP	Pp
p	Pp	pp

If there are 2400 offspring, ¼ of 2400 = 600.

15. Suppose you have a dog that you know is heterozygous for seven different genes, which we'll just call genes A, B, C, D, E, F and G. You mate this dog with one that is heterozygous for all of the genes except gene E: for this gene, the dog is homozygous recessive. What fraction of the offspring would you expect to show both the recessive phenotype for gene D and the recessive phenotype for gene E?

Remember: “divide and conquer!” Here, we only care about the D and E genes, so just ignore everything else.

The first dog is heterozygous for D and homozygous for E, the other is heterozygous for both, so:

Dd × Dd → ¼ of all offspring will be dd

ee × Ee → ½ of all offspring will be ee

altogether, ½ of ¼ or 1/8 of all offspring will be both dd and ee.

16. A pure-breeding pea plant with round seeds and white flowers is crossed with a pure-breeding plant that has wrinkled seeds and purple flowers. What will the F_1 offspring look like? If two F_1 plants are crossed, what phenotypes will be expected in the F_2 generation, and in what proportions?

We know from above that round and purple are both dominant traits, so for the seed-shape gene, R =round and r =wrinkled. For the color gene, P =purple and p =white.

The pure-breeding parents must have been $RRpp$ (which can produce only Rp gametes; remember the gametes get one allele of each gene) \times $rrPP$ (which can produce only rP gametes). Their F_1 offspring must therefore be $RrPp$ -- all round and purple.

Now, we cross $RrPp \times RrPp$. Each of these parents can make four different types of gametes: RP , Rp , rP and rp . If you use the Punnett square method, you should get something like this (I used solid colors to represent round-seeded plants with purple or white flowers and stripes to represent wrinkled-seeded plants with purple or white flowers):

	RP	Rp	rP	rp
RP	$RRPP$	$RRPp$	$RrPP$	$RrPp$
Rp	$RRPp$	$RRpp$	$RrPp$	$Rrpp$
rP	$RrPP$	$RrPp$	$rrPP$	$rrPp$
rp	$RrPp$	$Rrpp$	$rrPp$	$rrpp$

From here, we can simply count squares and see that 9/16 will be round and purple ($RRPP$, $RRPp$, $RrPP$ and $RrPp$), 3/16 will be round and white ($RRpp$ and $Rrpp$), 3/16 will be wrinkled and purple ($rrPP$ and $rrPp$) and 1/16 will be wrinkled and white ($rrpp$).

17. When humans interlace their fingers, crossing left thumb over right thumb is a dominant trait. Two left-over-right parents have a right-over-left daughter. What are the genotypes of the parents and their daughter?

We can't immediately tell the genotype of a left-over-right person, because that's the dominant trait, so the person could be homozygous or heterozygous. However, we know that the daughter is homozygous for the recessive right-over-left trait, because she shows the trait (and you must be homozygous to show a recessive trait).

So, if we let L =left-over-right (dominant) and l =right-over-left (recessive), then the daughter's genotype is ll . This means each parent must have given her an l allele--and since her parents have the dominant phenotype but gave a recessive allele, they must both be heterozygous, Ll .

18. Another trait Mendel looked at was height; tall is dominant over dwarf in peas. A pure-breeding tall, white-flowered, round-seeded pea plant is crossed with a pure-breeding short, white-flowered, wrinkled-seeded plant. Give the genotypes and phenotypes of its offspring.

This looks harder but really isn't. We'll use the same symbols as above, plus T for tall and t for dwarf. Now, the two parents are $TTppRR$, which can produce only TpR gametes, and $ttpprr$, which can produce only tpr gametes. Putting these gametes together gives us offspring that are all $TtppRr$, with the phenotype tall, round and white.

19. How many different kinds of gametes can the offspring of #17 produce? What will be the expected genotypes and phenotypes resulting from a cross between two of these individuals?

There are only four kinds of gametes for the **TtppRr** plants, since all the gametes must get a white allele for the color gene. **TpR**, **Tpr**, **tpR** and **tpr** are the four combinations. The cross then actually works out just like any dihybrid cross, even though there are three genes here, because there are only white alleles of the color gene in the cross so all offspring will be white. The results should be 9/16 tall, white, round; 3/16 tall, white, wrinkled; 3/16 short, white, round; and 1/16 short, white, wrinkled.

20. A plant has the genotype **AAbbCcDDEeff**, where each letter represents a different gene. This plant is crossed with another whose genotype is **AaBBCcddEEFF**. What fraction of its offspring will show the phenotype produced by the **c** allele?

Again, looks hard but isn't very. Although there are six genes shown here, the problem only asks about one of them, the "**C**" gene. Because different genes assort independently, we can ignore all the others and just think about this one gene. Then, our cross is really just **Cc** × **Cc**. From there, it should be easy to figure out that $\frac{3}{4}$ of the offspring will be either **CC** or **Cc** and show the dominant "**C**" phenotype, while $\frac{1}{4}$ will be **cc** and show the recessive "**c**" phenotype.

21. You notice that a pea plant in your garden has yellow seeds. This is a dominant trait (green is recessive), so your plant could be either homozygous for the yellow allele, or it could be heterozygous. How could you find out which is true??

Let **Y**=yellow, **y**=green. To find the genotype of the mystery plant, do a testcross between this plant and a homozygous recessive, **yy**, plant (green). If the original plant was **YY**, then the cross is **YY** × **yy** and all the offspring should be **Yy**, yellow. But, if the original plant was **Yy**, then the cross is **Yy** × **yy**, and half the offspring would get a **y** gamete from the unknown parent and be **yy**, green, while the other half will get **Y** and be **Yy**, yellow. (You could draw a 1×2 Punnett square to show this.)

22. Your yellow-seeded pea plant also has round seeds, another dominant trait. You cross it with a plant that has green, wrinkled seeds. About half have round, yellow seeds while the other half have wrinkled, yellow seeds. What was the genotype of the original plant?

The cross here is **Y? R?** × **yyrr**.

First of all, notice that all the offspring have yellow seeds. This means that all the offspring are getting a **Y** allele from the mystery parent (they all get a **y** from the tester). Then, the mystery parent must be homozygous, **YY**.

Now, look at round vs. wrinkled. Half the offspring are wrinkled, so half must've gotten an **r** allele from the mystery parent. The other half got **R** and came out round. So, the mystery parent must be **Rr**, heterozygous.

The genotype of the original parent is therefore **YYRr**.

23. An individual whose genotype is **AABbCc** is crossed with an individual who is heterozygous for all three of these genes.

- a. List the gametes that the **AABbCc** parent could produce.

ABC, **ABc**, **AbC**, **Abc**

- b. If this cross produces 250 offspring, how many would you expect to have the genotype **AAbbcc**? (Hint: you shouldn't have to do a whole large Punnett square!).

Quickest way to do this problem is to look at the three genes separately. For "**A**," the cross is **AA** × **Aa**. Half of the offspring should therefore be **AA** (and half **Aa**). For "**B**," the cross is **Bb** × **Bb**, and you should recognize right away that $\frac{1}{4}$ of the offspring will be **bb**. "**C**" is the same: **Cc** × **Cc**, $\frac{1}{4}$ will be **cc**. Then just put them together: the probability of **AAbbcc** is $\frac{1}{2} \times \frac{1}{4} \times \frac{1}{4}$, or $\frac{1}{32}$. The number of offspring that should have this genotype is $250/32$, or about 8.

24. While picking (and eating!) strawberries in your garden one day, you notice a plant whose berries have an unusual, pleasantly tangy flavor. You decide to put what you've learned in Bio 102 to practical use and finance the rest of your education by breeding tangy berries.

Unfortunately, you can never find plants that are pure-breeding! Every time you cross two plants with tangy berries, most of their offspring produce tangy berries, but there are always some offspring that make berries that are much too sour and some offspring that produce ordinary, sweet berries.

Give a simple genetic explanation for these results (in words). Then, diagram a cross between two tangy plants and show why it will always give the results described.

This looks like a case of incomplete dominance. The tangy berries are heterozygous and have a phenotype (flavor) in between homozygous sweet and homozygous sour. Thus, tangy berries can never be pure-breeding.

If F^S = sweet allele and F^R = sour allele, then the $F^S F^R$ genotype produces tangy berries.

A cross between two tangy berries would always be $F^S F^R \times F^S F^R$

Offspring will always be:

- $\frac{1}{4} F^S F^S$, sweet
- $\frac{1}{2} F^S F^R$, tangy
- $\frac{1}{4} F^R F^R$, sour

25. An individual heterozygous for each of five genes ($AaBbCcDdEe$) is crossed with another individual who has the same genotype.
- How many different gametes can each of these parents produce?
There are five genes, and for each gene, there are two different gametes (A or a , B or b , etc.). So, there are $2 \times 2 \times 2 \times 2 \times 2$ (or 2^5) possible combinations, or 32 different gametes.
 - What fraction of their offspring would show the phenotype associated with the recessive allele of gene D ?
Much easier than it might sound! If all we care about is gene D , then the Law of Independent Assortment says we can break up the problem and look only at gene D . Then, the cross is just $Dd \times Dd$ and clearly $\frac{1}{4}$ of the offspring will be dd and have the recessive phenotype.

True or False? Read carefully: a question is false unless it is completely true!

- T ☒ F ☐ 1. Self-fertilization of a pea plant produces the same result as if that plant were crossed with another of identical genotype.
- T ☒ F ☐ 2. One parent in a testcross is always homozygous recessive for all genes being studied; this kind of cross can be used to determine the genotype of an unknown individual.
- T ☐ F ☒ 3. Mendel's law of independent assortment states that a gamete gets only one allele for each gene.
- T ☐ F ☒ 4. Mendel's law of segregation states that alleles of two different genes segregate independently during gamete formation.
- T ☒ F ☐ 5. The phenotype of a heterozygous individual is used to determine dominance.

- T ☐ F ☒ 6. The I^A and I^B alleles that determine human blood type are a good example of incomplete dominance.
- T ☐ F ☒ 7. Recessive alleles that cause fatal genetic disorders are very uncommon, because an individual that inherits one of these alleles will die.
- T ☒ F ☐ 8. For a gene showing complete dominance, a recessive allele has no effect on the phenotype of a heterozygous individual.

Multiple choice: Unless otherwise directed, circle the one best answer (2 points each)

1. Suppose a mutation occurs, resulting in an altered amino-acid sequence for some protein. This mutation has produced a new:
- A. Gene
 - B. Chromosome
 - C. Allele
 - D. Quaternary structure
 - E. Character

Matching:

1. Match each of the following genetic terms with the one statement that best describes or explains it.

<u>E</u>	Gene	a. Results from the fusion of a sperm and egg cell
<u>H</u>	Genotype	b. Produces the phenotype of a heterozygote
<u>L</u>	Phenotype	c. Observed phenotypically only when homozygous
<u>J</u>	Gamete	d. Separation of two alleles
<u>F</u>	Independent assortment	e. An inherited factor
<u>B</u>	Dominant	f. Results in 9:3:3:1 ratio in F ₂ generation of a dihybrid cross
		g. Specific form of an inherited factor
		h. Combination of alleles an individual has
		j. Haploid cell
		k. Diploid cell
		l. An observable characteristic
		m. Having two different alleles

2. Each scenario below describes the alleles for some gene that are present in a heterozygous individual. Match each one with the term from the list on the right that best describes the situation. One letter per blank, use the letters once only.

<u>A</u>	Allele #1 encodes a functional enzyme; allele #2 encodes a non-functional version of the enzyme. The cell needs at least 40% of normal enzyme activity in order to have a normal phenotype.	a. Complete dominance
<u>B</u>	Allele #1 encodes a functional enzyme that makes a blue pigment; allele #2 encodes a non-functional version of the enzyme. The cell needs at least 90% of normal enzyme activity in order to be its normal, dark blue color.	b. Incomplete dominance
<u>E</u>	Allele #1 encodes functional tyrosinase. Allele #2 encodes a mutant version of tyrosinase that can't bind pyrocatechol but can catalyze a different reaction involving phenylalanine.	c. Overdominance
		d. Epistasis
		e. Codominance