# Penguin Prof Helpful Hints: How to Solve Genetics Problems

## Important:

**Remember—the most important thing is to stay organized and consistent . Genetics problems are solved entirely by logic!**

## How to Start

Begin by writing out all of the information you have about the gene(s) and alleles in question. If you aren't given symbols to use, follow these rules:

1. All alleles of the same gene must be given some version of the same symbol
2. If you have complete dominance, assign a capital letter to the dominant allele and a lower case letter to any recessive allele(s). Use the letter which describes the dominant phenotype (for example, if you have two colors green and blue and if green is dominant over blue, use 'G' for green and 'g' for blue. Don't use 'B' or 'b' for blue - using more than 1 letter means more than 1 gene!)
3. If you have incomplete dominance, use superscripts rather than upper and lower case letters, since the latter encourage you to think in terms of complete dominance.
4. If you are dealing with an X-linked gene, use the X and Y and make sure to use the allele as a superscript on the X (for example, use $X^cX^+$ for a female heterozygous for color-blindness and use $X^cY$ for a color-blind male.)

## The Punnett Square

1. Once you have figured out the gametes for your two parents, construct a table with one column for each of the mother's gametes and one row for each of the father's gametes.
2. The small boxes inside the table represent the possible types of fertilization events which these two parents can produce.

| | A | a |
|---|---|---|
| A | | |
| a | | |

## Filling in the Squares

- Fill in each square with a combination of the mother's alleles from the top of the column and the father's allele from the left of the row. By convention, in a heterozygous genotype the symbol for the dominant allele is written first (Aa and not aA, even though it means exactly the same genotype). Be consistent.

| | A | a |
|---|---|---|
| A | AA | Aa |
| a | Aa | aa |

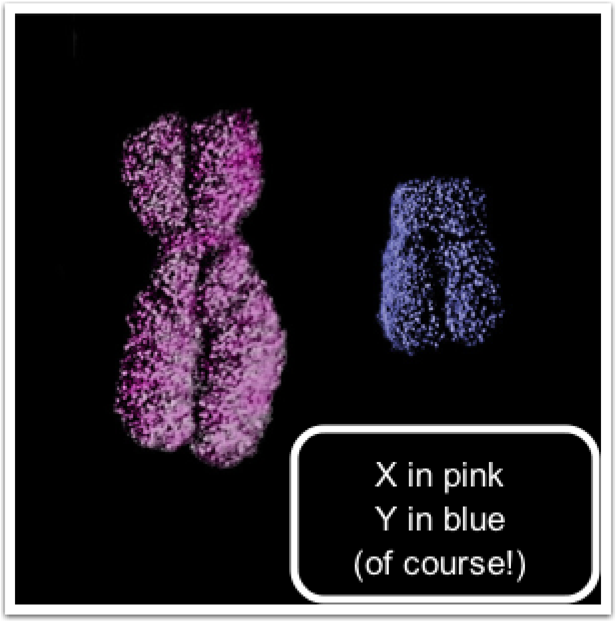
## Determine the Genotypic Ratio

- Once the boxes are all filled in, determine all the different kinds of genotypes contained in the boxes and then count how many times each different genotype occurs in the table; this will give you the genotypic ratio. Remember, the order of the alleles does not matter - so "Pp" is the same genotype as "pP." Caution: a ratio never consists of just numbers - it must also include the descriptions which go with the numbers (for example, 0.75 Pp).

## Determine the Phenotypic Ratio

- To get the phenotyic ratio, ask yourself, "how many of these genotypes produce the same phenotype?" The answer to this question will depend upon the dominance relationships between the alleles in question. Add together the numbers for the genotypic classes which will give the same phenotype to find the phenotypic ratio.
- Complete dominance: If you have complete dominance, your homozygous dominant genotype and your heterozygous genotype will produce the same phenotype. Therefore, you add those two classes together. The homozygous recessive remains by itself.
- Incomplete or Codominance: If you have incomplete of Codominance, no two of your genotypic classes will produce the same phenotype, so the numbers in your phenotypic ratio will be the same as those in your genotypic ratio.

## Sex-Linked Traits (Traits Carried on the X or Y Chromosome)




REMEMBER: Males are XY and Females are XX (in humans - not always true in other species!)

1. The basic approach is the same as to the single gene cross above, except that you must be careful to <u>report offspring by gender</u>. Don't simply lump the male and female offspring together. In sex linkage problems, gender is frequently a very important part of the phenotype.
2. If you are dealing with an X-linked gene, use the X and Y and make sure to use the allele as a superscript on the X (for example, use $X^cX^+$ for a female heterozygous for color-blindness and use $X^cY$ for a color-blind male.)
3. You will construct your Punnett's square exactly as above, except that you will use the Y as the male's second gamete. <u>If you fail to do this, your parents will have no male offspring</u>.
4. Report your phenotypic ratio by gender—males separate from females. This won't always matter, but it is often a vital part of the phenotypic results of your mating.
5. In order to show an X-linked recessive trait, a female must inherit the recessive allele from both parents; a male must inherit it only from one parent; for this reason, X-linked traits are much more common in males than in females.

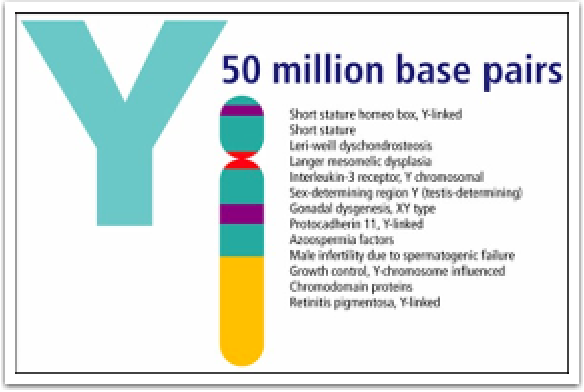
## An Example with Color-Blindness, a Sex-Linked Trait

If you cross a heterozygous female with a color-blind male, this is the Punnett Square of the possible offspring. Notice that the phenotypic ratio is:

50% of females are normal (they are heterozygous - silent carriers of the trait)
50% of females will be color-blind
50% of males will be normal
50% of males will be color-blind

| | $X^+$ | $X^c$ |
|---|---|---|
| $X^c$ | $X^+X^c$ | $X^cX^c$ |
| Y | $X^+Y$ | $X^cY$ |

## Holandric Traits




Y-linked (holandric) traits are the easiest of all traits to follow; every male passes his Y chromosome to all of his male offspring and to none of his female offspring. Every male inherits his father's entire Y chromosome. Therefore, as long as you have an unbroken male line of descent, all males thus connected will have copies of the same Y chromosome. If Dad's got it, so do all of his sons; so does his father and his father's father. Unfortunately, there are very few Y-linked traits known.

## Basic Statistics: AND vs. OR

- A Punnett's square is actually a statistical table—a device which allows you to "do" statistics without doing the calculations. But genetics is a statistical science, and problems can also be solved using statistics.
- When solving a genetics problem, you are calculating probabilities. The probability of a particular event is the "chance" that event will occur. It's a prediction.
- Probabilities are expressed as decimals.
- Probability values range from 0 to 1.0. A probability of 1.0 is a certainty - it's equivalent to a chance of 100%. The probability that, if you toss a coin into the air, it will come back down (given that we are on the surface of the Earth and that there are no obstacles to prevent its descent) would be 1.0.
- A probability of zero means the event will never happen. The probability of tossing a penny into the air and have it come down magically changed into a quarter is zero.

- The probabilities of all possible outcomes for an event must add up to 1.0. For example, if you have a bag full of marbles, some of which are red and some of which are blue, the probability that you will randomly pull out a red marble and the probability that you will randomly pull out a blue marble must add up to 1.0. Those are the only possible outcomes, so they have to add up to 100% of the possible outcomes.
- The mathematically formal way to express probabilities uses the letter "P" to mean probability. For our two examples above, the formal expressions would be:

  P (tossed coin will fall) = 1.0
  P (tossed penny will turn to quarter) = 0.0

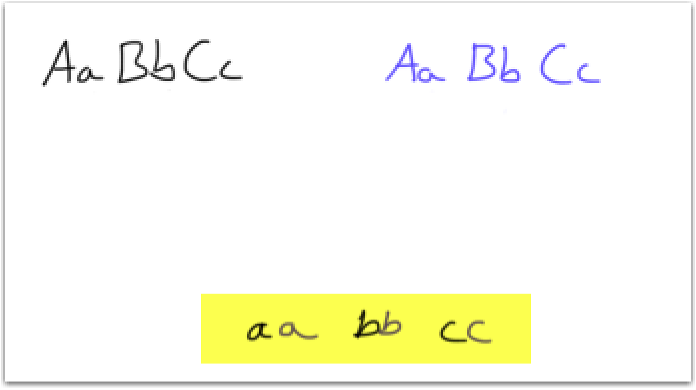
- To calculate the probability that two independent events will occur at the same time, we multiply their individual probabilities. For example, if the probability of John Doe coming to class on a test day is 0.25, and the probability that he will pass any exam is 0.1, then the probability that he will come to class **and** pass a test is (0.25)x(0.1) = 0.025. Note the word "and" in the previous sentence - if the occurrence of two events includes the word "and," you need to multiply probabilities. We'd express this as P (John comes to class **and** John passes exam) **= 0.25 x 0.1 = 0.025.**

- If more than one event will satisfy the conditions of our prediction, we add their probabilities. For example, Suzie Que's parents have promised her a trip to Hawaii if she earns a grade higher than a C in her biology class. The probability that she will earn a B is 0.4. The probability that she will earn an A is 0.1. She wins the deal if she earns an A **or** a B, so P (A or B) = **0.4 + 0.1 = 0.5.** Suzie has a 50% chance to earn herself a trip to Hawaii. Note the word "**or**" in the description. "Or" generally means you add probabilities.

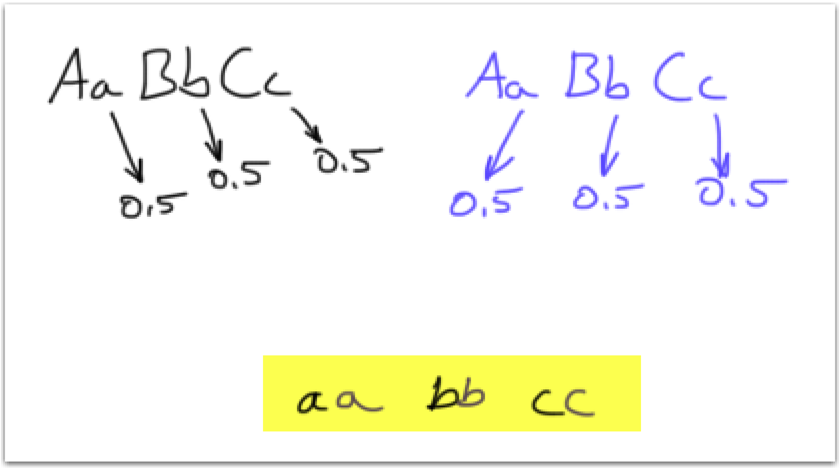
# Using Statistics to Solve Genetics Problems

- For a monohybrid cross, a Punnet square is quick and easy. For 2 or 3 traits (or more), those squares get big and ugly REAL fast.
- By understanding the power of multiplication ('this allele AND this allele AND this allele") you can make your life a lot easier by simply multiplying individual probabilities together to get your answer.

For example, in the cross **AaBbCc** with **AaBbCc**, find the probability of an offspring that is **aabbcc**.

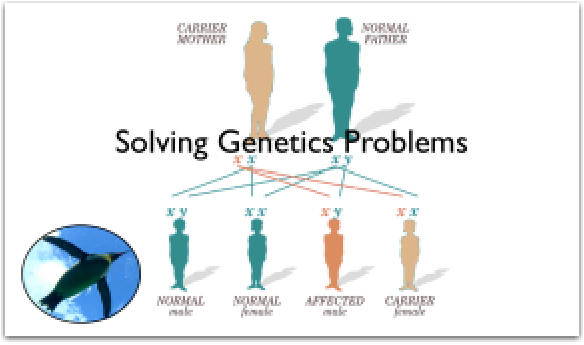



# Solution




Realize that each parent is heterozygous for all 3 alleles, so the probability that each parent will donate the recessive allele is 0.5. The offspring we want is homozygous recessive for all three traits, so you need to multiply all those probabilities together... and you'll get **1/64 or 0.0156.**

## For More Help...




Watch my "How to Solve Genetics Problems" video!