Probability

Genetics relies heavily on probability. There is some probability (likelihood) that you get a disorder if your parents have the alleles for it. Everyday examples of probability are easy to understand and can help you grasp the genetics ideas. To begin, it is important you know two rules the product and sum rules also known as the “and” and “or” rules.

Explanation of rules:

The names of these rules explain when and how to use them. The product rule, also known as the “and” rule, is used when two things have to happen together to get the desired outcome. You may see the word “and” in a sentence to remind you to use this rule. You will multiply the probabilities of each individual action in order to get the probability of the desired outcome.

The sum rule, also known as the “or” rule, is used when you have multiple options that are acceptable and you just need one to occur. You may see the word “or” in a sentence to remind you to use this rule. You will add the probabilities of each individual action in order to get the probability of the desired outcome. As a reminder, you can only add fractions that have the same denominator.

Example:

To explain these rules, read the following example. If you want to flip a coin to get a heads and roll a die to get a number 1, you have two things that must happen together to get the outcome you want. When you see the word “and” in a sentence or you know that multiple things together must occur to get the desired outcome, you can use the product rule. Below you can see the math that shows how to find the probability of this desired outcome:

$\frac{1}{2} \times \frac{1}{6} = \frac{1}{12}$; where there is one heads side of a two-sided coin and only one number 1 on a six-sided die.

To compare the rules, the next example is slightly changed. In an example where you want to flip a coin and get a heads or roll a die and get a number one, you have two outcomes that are acceptable and you only need one of them to occur. This example illustrates an “or” rule. Below you can see the math that shows how to find the probability of this desired outcome:

$\frac{1}{2} + \frac{1}{6}$; where there is one heads side of a two-sided coin and only one number 1 on a six-sided die.

A common denominator is found, and then the fractions can be added. $\frac{3}{6} + \frac{1}{6} = \frac{4}{6} = \frac{2}{3}$

Note: If you ever are unsure about which rule to use, rewrite the problem in words using the word “and” or “or”.

Practice:

1. There is a bag of 3 red marbles, 2 green marbles, 4 orange marbles, and 1 blue marble.
   a. What is the probability of randomly pulling out a single green marble from the bag with your eyes closed?

      There are a total of 10 marbles. The probability of a green marble is $\frac{2}{10} = \frac{1}{5}$

   b. What is the probability of randomly pulling out one orange marble from the bag with your eyes closed?

There are a total of 10 marbles. The probability of an orange marble is $\frac{4}{10} = \frac{2}{5}$

c. What is the probability of pulling out a green marble, returning it to the bag, and then pulling out an orange marble?

The probability of a green marble is $\frac{1}{5}$ and the probability of an orange marble is $\frac{2}{5}$.

This is a product rule problem because of the word "AND". $\frac{2}{5} \times \frac{1}{5} = \frac{2}{25}$

d. What is the probability of pulling out a blue or a red marble on your first try?

There are 3 red marbles and 1 blue marble. This is a sum rule (or rule) problem. $\frac{3}{10} + \frac{1}{10} = \frac{4}{10} = \frac{2}{5}$

2. Two heterozygous grey parent rats are mated. They produce both grey and white offspring. Assume that fur color is controlled by a single gene for the following problems.

a. Define your alleles

There are numerous answers possible for this question. You must have both the dominant and recessive alleles defined (and no genotypes), you must use the same letter for both alleles, and you must define the dominant allele as being grey.

Hint: Try to avoid X and Y to define alleles so these can refer to chromosomes later in the semester. Avoid letters you cannot tell the uppercase from the lowercase when possible; do not use Z, O, or U.

Example answer:

A-Grey fur; a=white fur

Hint: The reason you know that grey fur is the dominant allele is because the heterozygous rats have grey fur as their phenotype. Heterozygous individuals express the dominant allele. The only time a recessive allele will be expressed is in a homozygous recessive individual. Dominant alleles mask (hide) recessive alleles so they are not expressed.

b. Draw a Punnett square detailing this cross.

	A	a
A	AA	Aa
a	Aa	aa

c. What are the possible gametes that each rodent parent could donate to an offspring?

Both parents will have 50% of their gametes with a dominant (grey fur) allele and 50% of their gametes with a recessive (white fur) allele.

d. What is the probability of an offspring being produced that gets a dominant allele for fur color from Dad and a dominant allele for fur color from Mom? Show your work and state if this example uses a sum or product rule.

Probability of getting a dominant allele from Dad: $\frac{1}{2}$

Probability of getting a dominant allele from Mom: $\frac{1}{2}$

Probability of this fertilization $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ This is a product rule; the word "and" is directly in the problem.

e. Compare your answer from the problem above to your Punnett square. A Punnett square shows probability of a genotype in an offspring. The probability rules you know will help you work through genetics problems without drawing as many Punnett squares.

f. What is the probability of these rodents producing a white female offspring?
Hint: Take note of all phenotypes
This problem is an "and" problem; it asks what is the probability of having an offspring with a female phenotype and a white fur phenotype.
The probability of having a white fur offspring is $\frac{1}{4}$ and the probability of having a daughter is $\frac{1}{2}$ (controlled by the father donating a sperm with an X or Y chromosome). $\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$

Each time fertilization occurs, there is a one eight chance a white coated female offspring will be produced.

3. Parent 1 has a genotype of AaBBDdff and parent 2 is heterozygous for all genes. Answer the following questions by using the sum and product rules. Below are punnett squares to help you solve the problems:

	A	a
A	AA	Aa
a	Aa	aa

	B	b
B	BB	Bb
B	BB	Bb

	D	d
D	DD	Dd
d	Dd	dd

	F	f
f	Ff	ff
f	Ff	ff

a. What is the probability of an offspring with a heterozygous genotype?
Probability= Probability Aa × Probability Bb × Probability Dd × Probability Ff
$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{16}$

b. What is the probability of an offspring with a recessive phenotype?
In order to have a recessive phenotype, an organism must have only recessive alleles.
Probability= Probability aa × Probability bb × Probability dd × Probability ff.
$\frac{1}{4} \times 0 \times \frac{1}{4} \times \frac{1}{2} = 0$

c. What is the probability of an offspring with the following genotype: AaBbDdff?
Probability= Probability Aa × Probability Bb × Probability Dd × Probability ff.
$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{16}$

d. What is the probability of an offspring with a homozygous dominant genotype?
Probability= Probability AA × Probability BB × Probability DD × Probability FF.
$\frac{1}{4} \times \frac{1}{2} \times \frac{1}{4} \times 0 = 0$