

# Putting It All Together!

A **chromosome** is a string of **genes** that can be passed down to offspring.

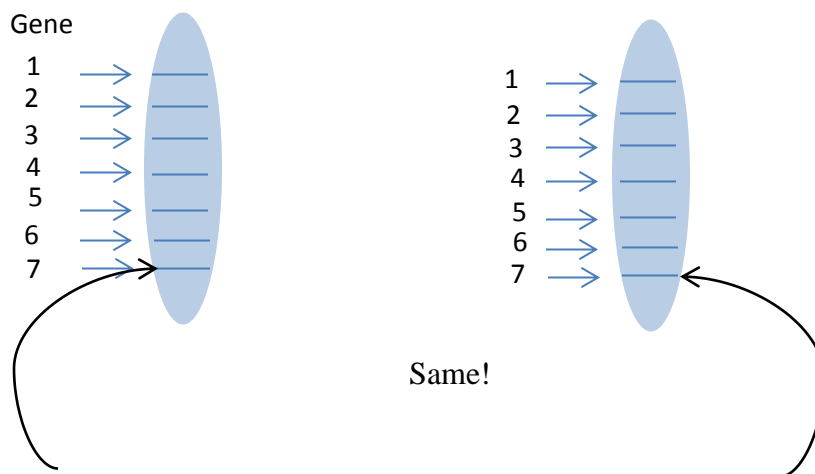
Diploid cells have 23 pairs of chromosomes:

22 pairs are **autosomes**

1 pair is **sex chromosomes** (XX or XY)

Each chromosome pair is **homologous**: the same size and with the same genes in the same order.

Example of homologous:



These two genes are for the same **TRAIT** (something about you)

There can be more than one variation for a trait. These variations are known as **alleles**.

Example:

Trait- hairline

Alleles- widow's peak and not widow's peak (strait)

These alleles can be **inherited** in different combinations.

The alleles that are inherited and mask the expression of another allele form are called **dominant alleles** (nothing to do with better or worse).

**Recessive alleles** are the ones masked by dominant alleles. The only way they get expressed is by inheriting two copies.

When discussing inherited traits, the trait is assigned a letter. For example, we'll use "H" for the trait "hairline".

The alleles are assigned a capital or lower-case of the letter depending on if they are dominant or recessive:

Widow's Peak = H = dominant  
No Widow's Peak = h = recessive  
(Strait hairline)

### **Genotype vs. Phenotype**

**Genotype** = the actual alleles, or genetic combination, inherited by the individual

**Phenotype** = the expression of the genotype

Example:

<b>Genotype</b>	<b>Phenotype</b>
HH	Widow's Peak
Hh	Widow's Peak
hh	Not Widow's Peak (strait hairline)

### **Homozygous vs Heterozygous genotypes** (same) (different)

<b>Genotype</b>	<b>Homo- or Hetero-</b>
HH	Homozygous
Hh (also called a carrier)	Heterozygous
hh	Homozygous

## The Punnett Square

A diagram that allows determination of genetic inheritance **probabilities** for each offspring from two parents.

When doing Punnett squares, keep the following in mind:

- A given person carries 2 copies of every gene (inherited one from mom and one from dad)
- The two copies are separated when the person makes their gametes for reproduction (this is Mendel's **Law of Segregation**)
- Each parent contributes one copy of each gene, or allele, to their offspring in fertilization.
- Alleles are inherited independently of other alleles, or at random (**independent assortment** during meiosis)

### Setting up the Punnett Square

- The Square must have one “rung” for each allele that could be contributed by a parent
- One parent's alleles on one side and the other parent's alleles on the other side

Example:

Mom = Hh (Mom can contribute alleles H and h); Dad = Hh (Dad can contribute alleles H and h)

	<b>H</b>	<b>h</b>	<b>← Dad's alleles</b>		
<b>H</b>	HH	Hh	1/4	HH	(25%)
			2/4	Hh	(50%)
<b>h</b>	Hh	hh	1/4	hh	(25%)
<b>↑ Mom's Alleles</b>					

The outcome of the Punnett Square yields probabilities for inheriting a certain genotype as well as phenotype. Remember that the genotype is the actual allele pair you inherit whereas the phenotype is the expression of the genotype.

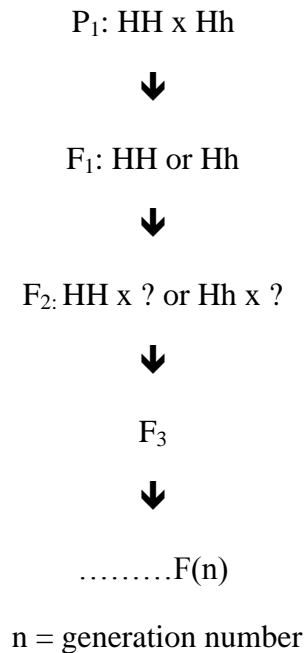
From the Punnett Square example above we get:

<b>Genotype</b>	<b>HH</b>	<b>1/4</b>	<b>25%</b>
<b>Genotype</b>	<b>Hh</b>	<b>2/4</b>	<b>50%</b>
<b>Genotype</b>	<b>hh</b>	<b>1/4</b>	<b>25%</b>
<b>Phenotype</b>	<b>Widow's Peak</b>	<b>1/4 + 2/4 = 3/4</b>	<b>75%</b>
<b>Phenotype</b>	<b>No Widow's Peak</b>	<b>1/4</b>	<b>25%</b>

### Generations

When tracking inheritance through generations each generation has a name. The original parents are "**P<sub>1</sub>**". Their offspring are known as the first filial generation (**F<sub>1</sub>**). The offspring of the F<sub>1</sub> generation are the second filial generation (**F<sub>2</sub>**), and so forth.

Example:



**Determining Probabilities for More than One Trait**

Each possible allele that can be inherited in a gamete gets its own “rung” on the Punnett Square.

How do you determine the possible gametes with more than one trait?

**F O I L** it!

“Firsts, outers, inners, lasts”

Example:

P<sub>1</sub>:                      FOIL                      x                      FOIL  
                                  HhDd    HHdd

**H = Widow’s Peak**  
**h = No Widow’s Peak**  
**D = Dimples**  
**d = No Dimples**

**Possible Gametes for each parent:**

Firsts	HD	Hd	}
Outers	Hd	Hd	
Inners	hD	Hd	
Lasts	hd	Hd	

Note that this parent can only make one type of gamete.

Number gametes possible:    4    1

Punnett Square looks like this:



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Punnett Square looks like this:

	<b>HD</b>	<b>Hd</b>	<b>hD</b>	<b>hd</b>		<b>Hd</b>	
<b>Hd</b>	HHDd	HHdd	HhDd	Hhdd	OR	HHDd	<b>1/4</b>
<b>Hd</b>	HHDd	HHdd	HhDd	Hhdd		HHdd	<b>1/4</b>
<b>Hd</b>	HHDd	HHdd	HhDd	Hhdd		HhDd	<b>1/4</b>
<b>Hd</b>	HHDd	HHdd	HhDd	Hhdd		Hhdd	<b>1/4</b>

Probabilities from 16-square:

Genotype	Probability	Phenotype*
HHDd	4/16 (= 1/4)	Widow's Peak and Dimples
HHdd	4/16 (= 1/4)	Widow's Peak and No Dimples
HhDd	4/16 (= 1/4)	Widow's Peak and Dimples
Hhdd	4/16 (= 1/4)	Widow's Peak and No Dimples

\*Phenotype probabilities: Widow's Peak and Dimples = 2/4 (50%); Widow's Peak and No Dimples = 2/4 (50%)

Probabilities from 4-square (compare the probabilities to the table above):

Genotype	Probability	Phenotype*
HHDd	1/4	Widow's Peak and Dimples
HHdd	1/4	Widow's Peak and No Dimples
HhDd	1/4	Widow's Peak and Dimples
Hhdd	1/4	Widow's Peak and No Dimples

\*Phenotype probabilities: Widow's Peak and Dimples = 2/4 (50%); Widow's Peak and No Dimples = 2/4 (50%)

**Is there an easier way than doing huge Punnett squares? YES!**

Multiplying probabilities from each trait will get you the same result quicker (requires that you understand how to multiply fractions).

Let's do a cross with **three traits** as an example.

H = Widow's Peak; h = No Widow's Peak

D = Dimples; d = No Dimples

T = Hitchhiker's thumb; t = No Hitchhiker's thumb

P<sub>1</sub> =                    HhDdtt                    x                    hhDdTT

The approach:

Do a Punnett Square for each trait separately and determine the probabilities for each trait:

		h	h	
H		Hh	Hh	Hh = 2/4
h		hh	hh	hh = 2/4

		D	d	
D		DD	Dd	DD = 1/4
d		Dd	dd	Dd = 2/4 dd = 1/4

		T	T	
t		Tt	Tt	Tt = 4/4
t		Tt	Tt	

Now for each possible combination, you only have to multiple the probabilities.

Example: What is the probability for an offspring with hhDDTt?

$2/4 \times 1/4 \times 4/4 = 8/64$  (or  $1/8$  if you reduce the fraction)

This offspring has No Widow's Peak, has Dimples and has a Hitchhiker's Thumb

**Now you try a few (answers at the bottom).**

What is the probability for an offspring with HhDdTt?

What is the probability for an offspring with hhddTt?

$HhDdTt = 2/4 \times 2/4 \times 4/4 = 16/64$  (or  $1/4$  if you reduce the fraction)

This offspring has a Widow's Peak, Dimples and a Hitchhiker's Thumb

$hhddTt = 2/4 \times 1/4 \times 4/4 = 8/64$  (or  $1/8$  if you reduce the fraction)

This offspring has No Widow's Peak, No Dimples and has a Hitchhiker's Thumb