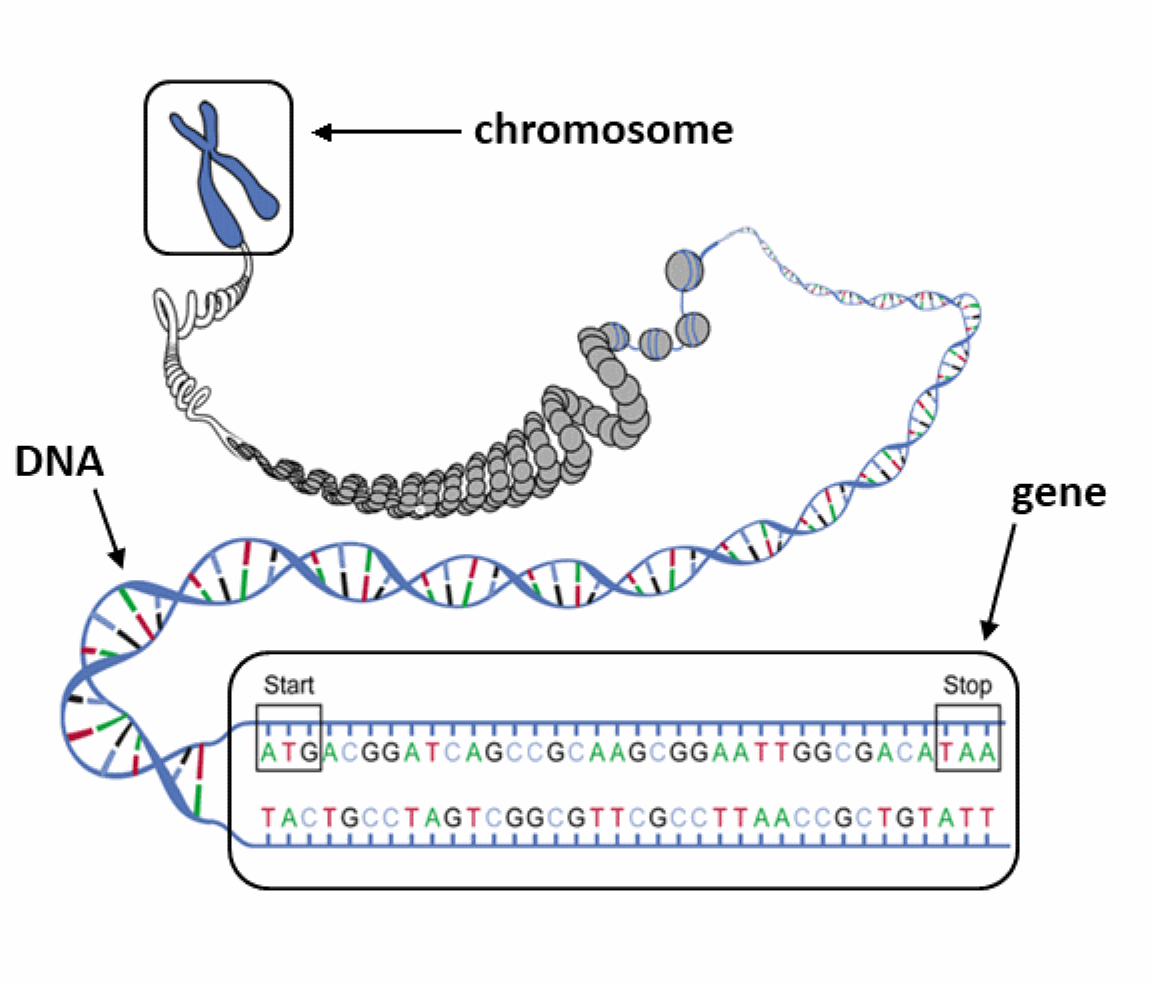
Heredity & Genetic Material

*Reproduction is a characteristic of all living organisms. During reproduction, the instructions for inherited traits are passed from parents to offspring through their genetic material. The passage of these genetic instructions from one generation to the next generation is **heredity**.*

Chromosomes, Genes & DNA

Genetic information is encoded in **DNA**. DNA is located in the **chromosomes** of cells. Chromosomes appear very dark (when viewed under a microscope) and are located in the cell nucleus, if the cell has one.



A gene is a section of DNA located on a chromosome.

Adapted from image courtesy of NIH.

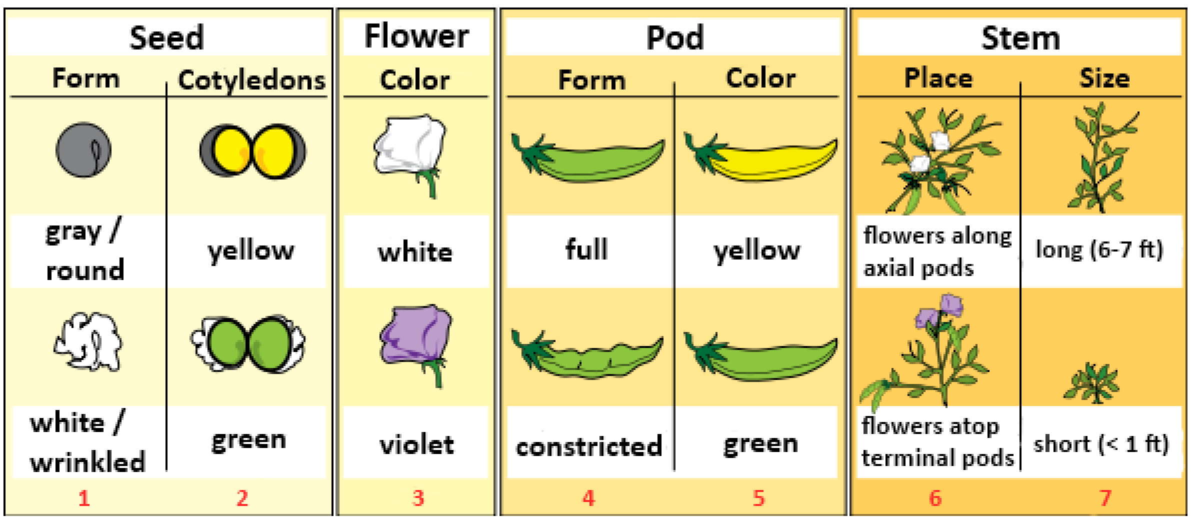
A section of a chromosome that controls a particular trait is a **gene**. Genes are a kind of blueprint for an organism. They contain all the information necessary to build, repair, and keep the organism running, including how to make all the different proteins and other materials the body needs.

Mendel's Laws of Genetics

Gregor Mendel's studies with pea plants formed the basis of three laws governing inheritance.

Mendel's Experiments

During the 1800s, Gregor Mendel studied genetic traits in pea plants. He selected seven different traits to study, including plant height, pea pod color, and flower color. Each of the traits that Mendel studied had two possible alleles, such as tall or dwarf for height and purple or white for flower color.



The seven traits of pea plants studied by Gregor Mendel during his genetic experiments.

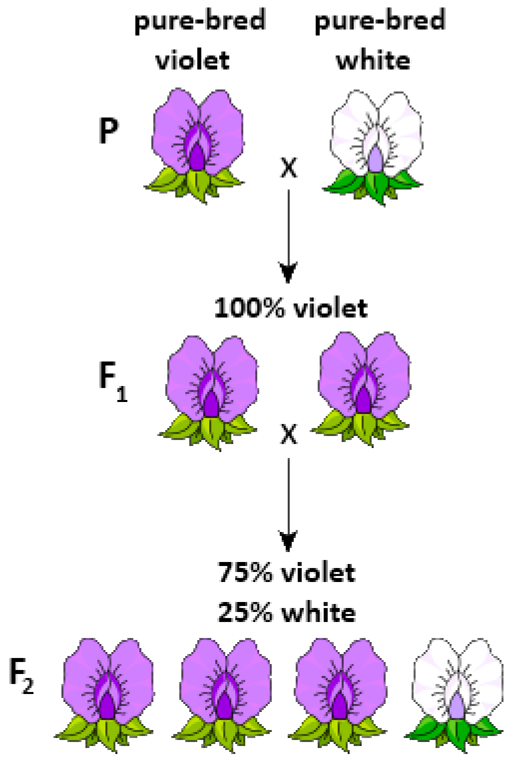
Adapted from image courtesy of Wikipedia.

Mendel began his experiments by obtaining **pure lines** of pea plants. These pure lines were groups that produced offspring with the same traits. For example, Mendel's pure line plants with purple flowers produced offspring that all had purple flowers. Mendel knew his lines were pure because each generation kept passing on the same traits to its offspring, but he did not yet know how these traits were passed. He would later understand that these pure lines were homozygous for several traits.

Test Cross

After obtaining the pure lines, Mendel crossed a pure line that had purple flowers with a pure line that had white flowers. He called this the **P generation** for *parent generation*. Once the pollinated flowers produced seeds, Mendel planted them. The cross of purple and white flowers resulted in **F_1 generation** offspring that all had purple flowers (100%).

Next, Mendel crossed two of the offspring from the F_1 generation. Both parents had purple flowers, but about ¾ of the resulting **F_2 generation** offspring had purple flowers, and about ¼ had white flowers.



Based on his data analysis, Gregor Mendel formulated three laws governing inheritance:

1. **The Law of Dominance**
2. **The Law of Segregation**
3. **The Law of Independent Assortment**

Law of Dominance

The **law of dominance** states that when an organism has two or more alleles for a trait, the allele that is expressed over the other alleles is considered **dominant**. The other alleles are considered **recessive**.

In Mendel's pea experiments discussed above, the allele for white flowers was recessive to the allele for violet flowers because the allele for violet flowers masks the allele that codes for white flowers.

Example 1:

A man and his wife have four children, all with freckles. The man does not have any freckles, but the wife does have freckles.

Why do all of the children have freckles?

All of the children have freckles because **they inherited a dominant allele for freckles** from their mother. From the Law of Dominance, it can be assumed that if the parents have different alleles for the same trait, but all of the offspring have the same allele for that trait, the inherited allele is dominant.

Law of Segregation

The **law of segregation** states that different alleles for the same trait separate when gametes are formed. Thus, a mother that is heterozygous for brown eyes (Bb) could pass either a dominant brown allele (B) or a recessive blue allele (b) for eye color to her offspring.

Example 2:

A plant with a red flower and a plant with a white flower are crossed, resulting in all red flowers. The offspring are heterozygous for flower color.

What allele(s) for flower color can the offspring plant pass on to its own offspring?

The plant can pass on the allele for **red** or **white** flower color to its offspring. A heterozygous organism has both a dominant and a recessive allele. Since the alleles separate into different gametes, an offspring could receive a gamete with one allele or the other.

Law of Independent Assortment

The **law of independent assortment** states that when pairs of alleles separate, they do so independently of each other. Thus, the alleles for hair color and the alleles for eye color in humans are not inherited together.

Example 3:

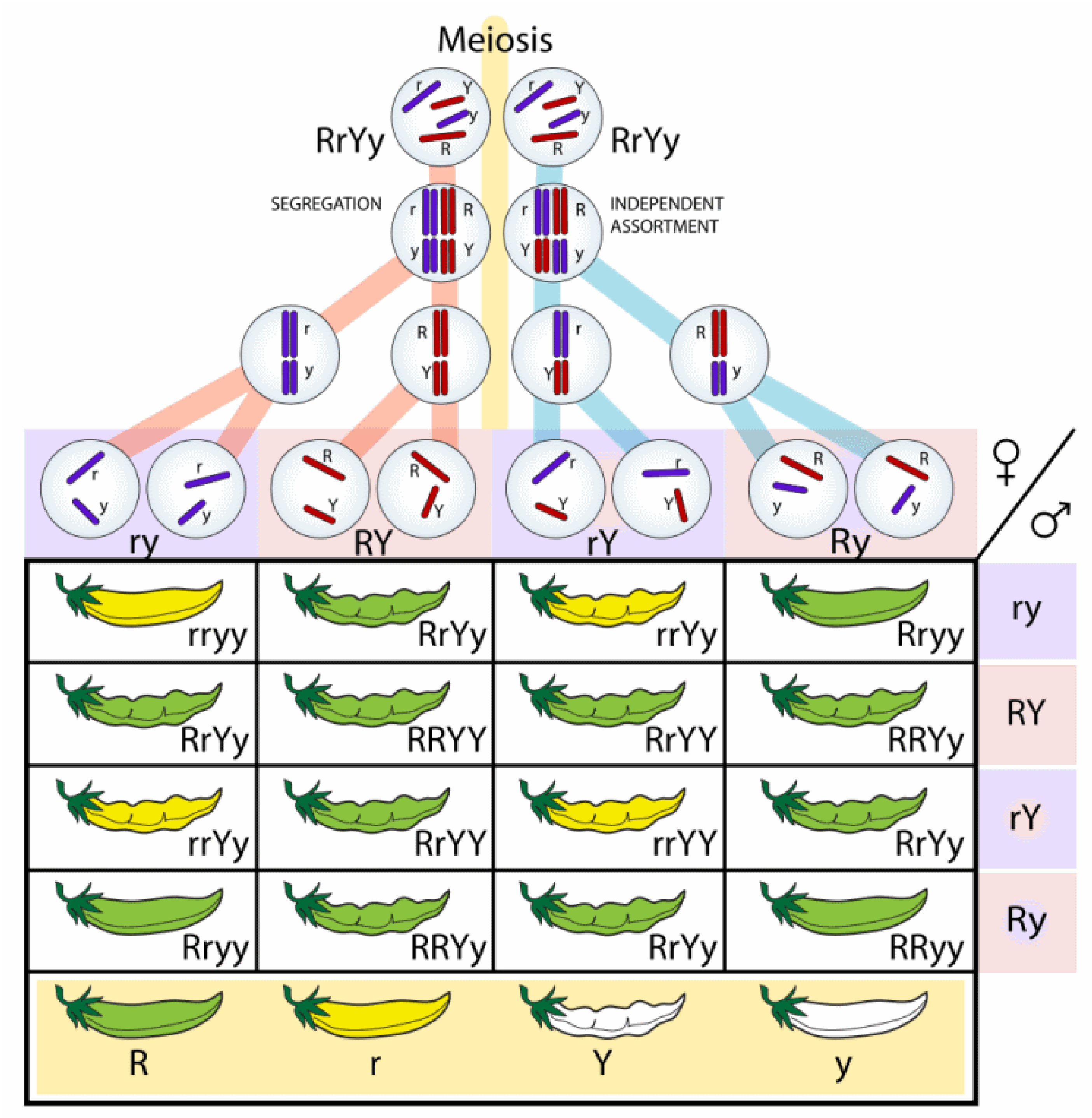
Margie's father is heterozygous for brown hair, a dominant trait, and homozygous for blue eyes, a recessive trait. Margie's mother is homozygous for blonde hair, a recessive trait, and heterozygous for brown eyes, a dominant trait.

Is it possible for Margie to inherit brown hair and brown eyes?

Yes. Since the alleles for each trait separate into gametes independent of each other, it is possible to inherit some traits from one parent and some from the other. Margie could inherit any one of several combinations of traits from her parents (blonde hair and blue eyes, brown hair and blue eyes, or blonde hair and brown eyes).

Demonstration of Mendel's Laws

The chart below shows all of the possible variations of offspring that could be produced from a cross between two pea plants that are both heterozygous for two traits: pod form and color.



During meiosis, alleles are separated and assorted independently. This results in greater variation among offspring.

Image is courtesy of Wikipedia.

Heredity

*The genetic makeup of an organism (set of genes present) is referred to as its **genotype**, and the visible traits that we can observe as a result of these genes are its **phenotype**.*

Allele Dominance

An **allele** is a variation, or one possible form, of a gene that codes for a particular trait.

Different alleles can be **dominant**, **recessive** or **intermediate**. Dominant alleles *mask* recessive genes, meaning that when a dominant and a recessive allele are both present, the dominant allele's phenotypic trait is observed.

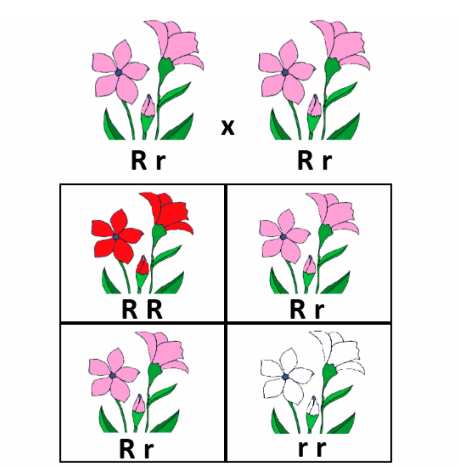
For example, if an individual pea plant has a dominant allele for tallness (T) and a recessive allele for shortness (t), the observed phenotype of the pea plant is tall. This plant is **heterozygous** for the height gene and has genotype (Tt). Traditionally, a capital letter represents the dominant allele and a lowercase version of the same letter represents the recessive allele.

A **homozygous** plant is one that has two copies of the same allele. Both allelic copies may be dominant (e.g. TT - tall) or recessive (e.g. tt - short).

Incomplete Dominance

Some alleles produce intermediate traits. That is, if one allele is incompletely dominant over the other, then a phenotype that is intermediate between the two variations can be observed.

For example, some flowering plants have an allele for red (R) color and an allele for white (r) color. However, when the plant is a heterozygote (Rr), the plant produces pink flowers rather than red or white.

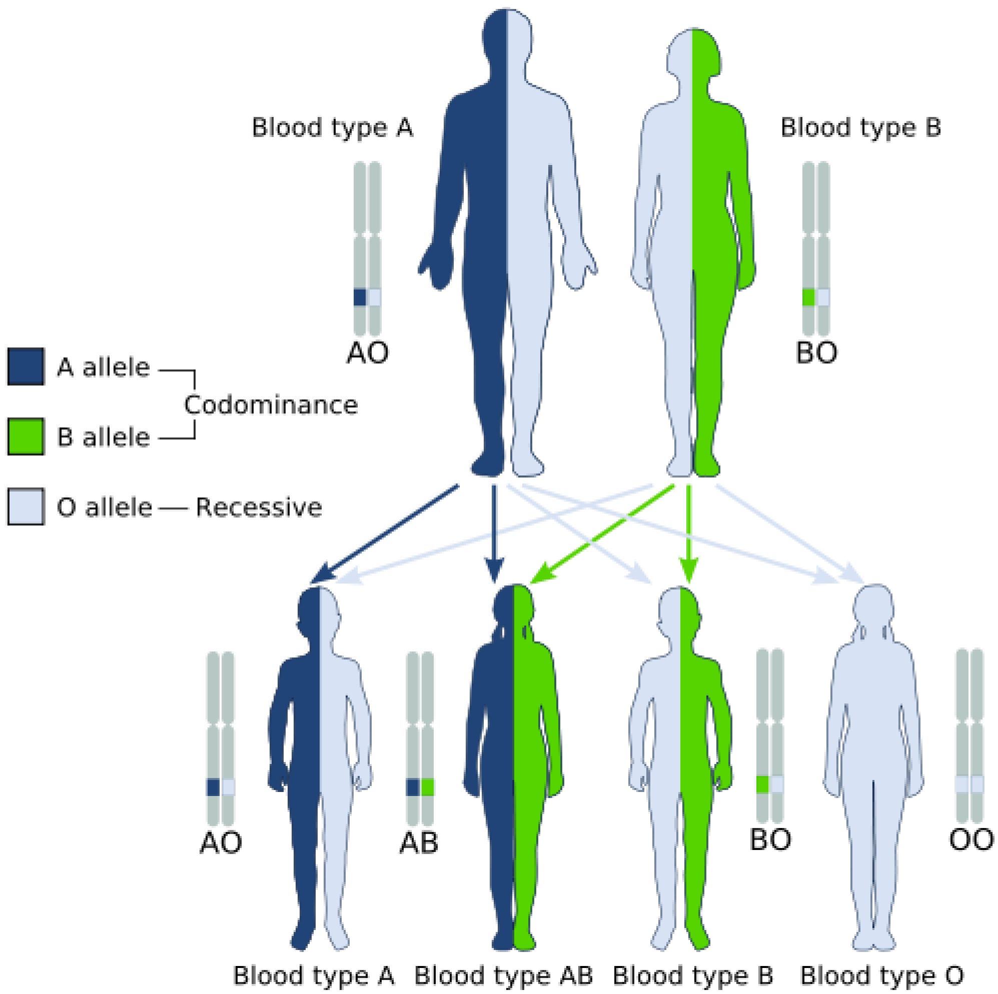


Pink flowers are a result of incomplete dominance. Whenever expressed traits show a blending of two alleles, it is usually due to incomplete dominance.

Codominance and Multiple Alleles

Codominance occurs when two alleles are equally dominant. In these circumstances, the alleles are expressed simultaneously, resulting in organisms that have some kind of mixed pattern. For example, a flowering plant with codominant color genes might exhibit white and red speckled flowers in the heterozygote.

In addition, some gene loci may have multiple traits, or more than two different traits present in varying amounts in a given population. When there are multiple traits, some genes may be dominant, others recessive, and still others may be incompletely dominant to one another. The ABO blood group is a good example of a gene locus with codominance and multiple alleles.



The alleles for A blood proteins and B blood proteins are codominant to each other. Unlike incomplete dominance, there is no blending. Someone with **AB** blood type will produce both A proteins and B proteins.

Image is courtesy of NIH and Wikipedia.

Polygenic Inheritance

Sometimes a particular phenotype may be determined by more than one gene. This is referred to as **polygenic inheritance**, where more than one gene locus has a similar and additive effect on the same trait. Traits that are coded for by many genes tend to have large variations. Skin color, for example, is determined by three separate gene loci in humans, each of which has alternate traits with an additive effect on how light or dark skin color is.

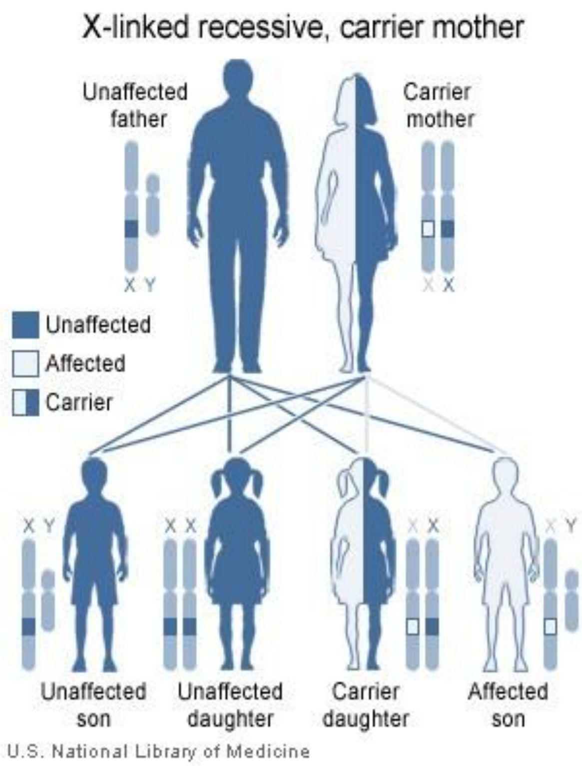
Sex-Linked Traits

Sex-linked traits are those carried on the **X chromosome**. Recall that in humans, a normal female has two X chromosomes. A normal male inherits an X chromosome from the mother and a Y chromosome from the father. Therefore, ***normal males inherit sex-linked traits only from their mothers.***

Recessive, Sex-linked Traits

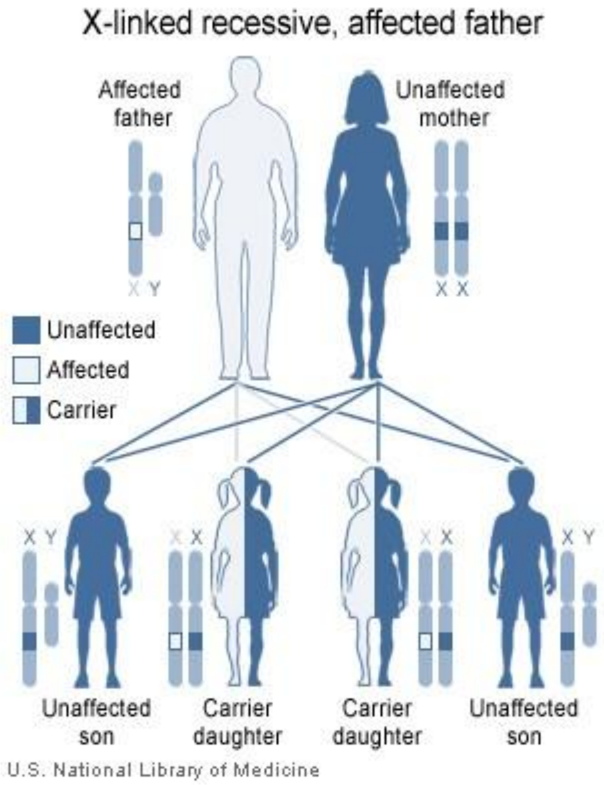
Recessive, sex-linked traits are more common in boys than girls. Some examples include:

- hemophilia
- colorblindness
- Duchenne muscular dystrophy



Males inherit recessive, sex-linked traits from their mothers.

Image is courtesy of U.S. National Library of Medicine.



The daughters of affected males will all become carriers. The sons will be unaffected because they do not inherit X chromosomes from their father.

Image is courtesy of U.S. National Library of Medicine.

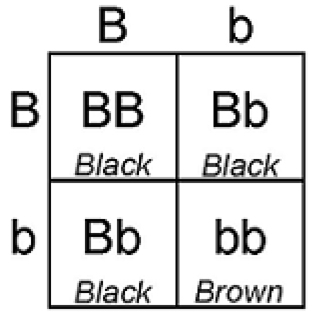
Punnett Squares

*A **Punnett square** is a chart which predicts all of the possible gene combinations from two parents for a particular trait.*

Punnett squares are named for the English geneticist, Reginald Punnett, who discovered some of the basic principles of genetics, including sex-linkage and sex-determination.

In a Punnett square, one parent's alleles are written across the top of a grid and the other parent's alleles are written down the left side of the grid. Then, the predicted genotypes of the offspring are determined inside the grid, like a multiplication table.

In the example below, two parents that are both heterozygous (**Bb**) for a coat color trait are crossed.



Since black coat color (**B**) is dominant over brown (**b**), the resulting progeny will approximately be:

- 3:4 (75%) black coated
    - 1:4 (25%) homozygous dominant (**BB**)
    - 1:2 (50%) heterozygous (**Bb**)
- 1:4 (25%) homozygous recessive (**bb**) and brown coated.

This is an example of a **monohybrid cross** because there is only one characteristic present (coat color). However, Punnett squares can also be used to predict the gene combinations of multiple linked traits.