Non-Mendelian Genetics

- Mendel's principles of inheritance are valid for all sexually reproducing species.
- However, often the genotype does not dictate the phenotype in the simple way Mendel’s principles describe.

Mendel cross-pollinated two contrasting, true-breeding pea varieties. This mating, or crossing, is called hybridization. The true-breeding parents are referred to as the P generation (parental generation), and their hybrid offspring are the F1 generation (first filial generation). Allowing these F1 hybrids to self-pollinate produced an F2 generation. Mendel’s quantitative analysis of the F2 plants from thousands of genetic crosses like these allowed him to deduce two fundamental principles of heredity, which have come to be called the law of segregation and the law of independent assortment.

## Codominance

Codominance describes inheritance where both alleles appear as part of the phenotype in the heterozygous offspring, i.e. feather color in chickens.

- **Black Chicken (BB)**
- **White Chicken (WW)**

\[
\begin{array}{c}
\text{Black Chicken (BB)} \\
\text{White Chicken (WW)} \\
\times \\
\text{F1: Speckled Chicken (BW)}
\end{array}
\]

Black and white feathers
2. **Incomplete dominance**, describes inheritance where one allele is not completely dominant over another in the heterozygous offspring, i.e. *snapdragon* and *hypercholesterolemia*.

3. When inheritance is controlled by a gene that has more than two alleles those characteristics are said to have **multiple alleles**, i.e. *human blood types* & *rabbit coat color*.

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**Blood Group (Phenotype)**

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Antibodies Present in Blood</th>
<th>Reaction When Blood from Groups Below is Mixed with Antibodies from Groups at Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>null</td>
<td>O, A, B, AB</td>
</tr>
<tr>
<td>A</td>
<td>P⁺⁺ or P⁺⁻ or P⁻⁻</td>
<td>Anti-B</td>
</tr>
<tr>
<td>B</td>
<td>P⁺⁺ or P⁻⁻</td>
<td>Anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>P⁺⁺⁺⁺ or P⁺⁺⁻⁻ or P⁻⁻⁺⁻ or P⁻⁻⁻⁺</td>
<td>—</td>
</tr>
</tbody>
</table>

Hypercholesterolemia is a condition in humans where there are dangerously high levels of cholesterol in the blood. People with this condition are prone to atherosclerosis and heart attacks. Hypercholesterolemia is even more serious in homozygous individuals (hh) which occurs in about one in a million people. Homozygous have about five times the normal amount of blood cholesterol and may have heart attacks as early as age two.

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**Coat color in rabbits is determined by a single gene that has at least four different alleles. Different combinations of alleles result in the four colors you see here.**

**Interpreting Graphics:** What allele combinations can a chinchilla rabbit have?

- **Key**
  - **C** = full color; dominant to all other alleles
  - **c⁺⁺** = chinchilla; partial defect in pigmentation; dominant to **c** and **c⁺⁻** alleles
  - **c⁺⁻** = Himalayan; color in certain parts of body; dominant to **c** allele
  - **c** = albino; no color; recessive to all other alleles

- **Chinchilla:** C⁺⁺⁺⁺, C⁺⁺⁻⁻, or c⁺⁺⁻⁻
- **Himalayan:** c⁺⁺⁺⁺ or c⁺⁺⁻⁻
- **Albino:** c⁺⁺⁻⁻
4. When a **single trait can be controlled by more than one gene** this type of inheritance is called **polygenic**, i.e. human skin color and human height.

![Skinpigmentation and eggs](image)

**F1 GENERATION**

\[
aabbcc \quad (\text{very light})
\]

\[
AABBCC \quad (\text{very dark})
\]

**AaBbCc**

**F2 GENERATION**

![F2 generation](image)

5. When a **single gene affect the phenotype in many ways** this type of inheritance is called **pleiotropy**, i.e. sickle-cell disease.

![Individual homozygous for sickle-cell allele](image)

Abnormal hemoglobin crystallizes, causing red blood cells to become sickle-shaped

**Sickle cells**

Accumulation of sickled cells in spleen

Kidney damage

Rheumatism

Kidney failure

Rheumatism

Pneumonia

and other infections

Paralysis

Pain and fever

Brain damage

Kidney failure

Anemia

Heart failure

Impaired mental function

Pain

Physical weakness

Impaired mental function

Heart failure

Brain damage

Spleen damage

The mutation in the DNA changes the shape of the hemoglobin molecule, allowing it to clump together. When red blood cells carrying mutant hemoglobin are deprived of oxygen, they become "sickle-shape," which may interrupt blood flow.

6. **Linked genes** are located on the same chromosome and tend to inherit together, therefore they violate **Mendel’s Law of Segregation**.

**Homologous Chromosome**

**Locus- Freckles**

Freckles

Freckles

**Locus- Red Hair**

Red

Red

**Linkage** A condition in which two or more genes do not show independent assortment. Rather, they tend to be inherited together. Such genes are located on the same chromosome. When the degree of recombination between linked genes is measured, the distance between them can be determined.

![Linkage](image)

**Test cross** is a mating between an organism with a dominant genotype and an organism that is **homozygous recessive** for that trait.

**Actual Results**

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Independent Assortment</th>
<th>Actual Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>ry</td>
<td>0.5</td>
<td>236</td>
</tr>
<tr>
<td>Ry</td>
<td>0.5</td>
<td>241</td>
</tr>
<tr>
<td>rY</td>
<td>0.5</td>
<td>239</td>
</tr>
<tr>
<td>ry</td>
<td>0.5</td>
<td>232</td>
</tr>
</tbody>
</table>

You would expect to see a ratio of recombinant phenotypes to parental phenotypes of 1:1:1:1 if the genes you were studying are located on different chromosomes.
Non-Mendelian Genetics

- **A test cross** is a mating between an organism with a dominant genotype and an organism that is homozygous recessive for that trait.

  \[ \text{GgLI} \times \text{ggll} \]

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>GL</th>
<th>GI</th>
<th>gL</th>
<th>gl</th>
</tr>
</thead>
<tbody>
<tr>
<td>gl</td>
<td>GgLI</td>
<td>Ggll</td>
<td>gLl</td>
<td>gll</td>
</tr>
</tbody>
</table>

**Morgan's observation** of disproportionate offspring led him to conclude that the genes for body color and wing size in Drosophila were usually transmitted together from parents to offspring because they were located on the same chromosome. Therefore, the **black body color gene and the vestigial wing gene are linked**. This means that the genetic location for these genes are found close to one another and on the same chromosome.

Non-Mendelian Genetics

7. **Sex Linked genes** are located on the sex chromosomes which do not inherit like autosomal chromosomes, therefore they violate Mendel's Law of Segregation.

Non-Mendelian Genetics

- **X-Linkage** refers to the inheritance of genes located on the X chromosome, Y-Linkage refers to the inheritance of genes located on the Y chromosome.

  - Red-green color blindness: difficulty with discriminating red and green hues due to the absence or mutation of the red or green retinal photoreceptors
  - Hemophilia A: a blood clotting disorder
  - Hemophilia B: a blood clotting disorder
  - Duchenne muscular dystrophy: rapid progression of muscle degeneration, eventually leading to loss of skeletal muscle control, respiratory failure, and death.
  - Becker's muscular dystrophy: a milder form of Duchenne, which causes slowly progressive muscle weakness of the legs and pelvis.

  - SRY: The main Y gene, which is the master gene that specifies maleness and male features. It is the single gene that sets off the initial cascade of hormone changes that make a person male.
  - Infertility: failure to produce sperm or a partial defect in sperm production resulting in the production of much lower sperm numbers.
Non-Mendelian Genetics

- The **SRY Gene** is located on the **Y chromosome** and provides *instruction for maleness*. This gene codes for a transcription factor called the **sex-determining region Y protein**.

- A **transcription factor** is a protein that attaches to specific regions of DNA and helps control the activity of particular genes.

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**Pseudoautosomal regions** are inherited just like any autosomal genes. Males have two copies of these genes: one in the pseudoautosomal region of their Y, the other in the corresponding portion of their X chromosome.

**Differential regions** contain genes which are not inherited like autosomal genes. This region makes up about 95% of the Y chromosome and is the location of the SRY gene. On the X chromosome, the differential region carries nearly 1,000 genes few of which have anything to do directly with sex. The inheritance of these genes follow special rules.