CHAPTER 11
GENETICS

Genetic discoveries 45 minutes
Like most human traits, skin color has a genetic basis; more than 100 gene products affect the synthesis and deposition of melanins.

In the picture of fraternal twins, both grandmas were European descent and both grandfathers are African.
Recurring inheritance patterns are observable outcomes of sexual reproduction.

Before the discovery of genes, it was thought that inherited traits resulted from a blend of parental characters.

Mendel was a monk with training in plant breeding and mathematics.
11.1 The work of Gregor Mendel

- **Genetics** = the study of heredity (passing down of characteristics from parent to offspring)
- **Gregor Mendel** = “the father of genetics”
  - Born in 1822 – Austrian monk
  - Worked with pea plants that were self-pollinating and true-breeding (the offspring always looked like the parent)
Important Genetic Terms

- **Trait** = a specific characteristic (pea color, hair color)
- **Gene** = the factors that are passed from parent to offspring (found at a locus on a chromosome)
- **Allele** = the different forms of a gene
Terms Used in Modern Genetics

- A **mutation** is a permanent change in a gene
  - May cause a trait to change

- A **hybrid** has nonidentical alleles for a trait
  - Offspring of a cross between two individuals that breed true for different forms of a trait are hybrids
Mendel’s Conclusions

- An individual’s characteristics are determined by factors (genes) that are passed from one parental generation to the next.

- **Principle of dominance** = some alleles are dominant and some are recessive
  - **Dominant** = need one allele (form of the gene) for the trait to be expressed
  - **Recessive** = need two alleles for the trait to be expressed
Genetics and probability

- **Dominant** alleles are written in **upper case** \( T = \text{tall} \)
- **Recessive** alleles are written in **lower case** \( t = \text{short} \)
- In this example:
  - There is a 50% chance that the plant the offspring will get a “\( T \)” allele
  - There is a 50% chance the plant will get a “\( t \)” allele
Even more genetic terminology

- **Genotype** = the genetic makeup of an organism
  - **Homozygous** = organisms that have two identical alleles for a gene (BB or bb)
  - **Heterozygous** = organisms that have two different alleles for a gene (Bb)

- **Phenotype** = the physical appearance of an organism
Mendel’s Pea Plants

- Mendel cross pollinated his true-breeding plants.
Mendel’s Monohybrid Experiments

<table>
<thead>
<tr>
<th>Trait Studied</th>
<th>Dominant Form</th>
<th>Recessive Form</th>
<th>F&lt;sub&gt;2&lt;/sub&gt; Dominant-to-Recessive Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed shape</td>
<td>5,474 round</td>
<td>1,850 wrinkled</td>
<td>2.98 to 1</td>
</tr>
<tr>
<td>Seed color</td>
<td>6,022 yellow</td>
<td>2,001 green</td>
<td>3.01 to 1</td>
</tr>
<tr>
<td>Pod shape</td>
<td>882 in ated</td>
<td>299 wrinkled</td>
<td>2.95 to 1</td>
</tr>
<tr>
<td>Pod color</td>
<td>428 green</td>
<td>152 yellow</td>
<td>2.82 to 1</td>
</tr>
<tr>
<td>Flower color</td>
<td>706 purple</td>
<td>224 white</td>
<td>3.15 to 1</td>
</tr>
<tr>
<td>Flower position</td>
<td>651 along stem</td>
<td>207 at tip</td>
<td>3.14 to 1</td>
</tr>
<tr>
<td>Stem length</td>
<td>787 tall</td>
<td>277 dwarf</td>
<td>2.84 to 1</td>
</tr>
</tbody>
</table>
Phenotype Ratios in a Monohybrid Experiment

True-breeding homozygous recessive parent plant

\[ aa \]

True-breeding homozygous dominant parent plant

\[ AA \]

F\(_1\) offspring

\[ \begin{align*}
    Aa & \quad Aa \\
    Aa & \quad Aa \\
    Aa & \quad Aa
\end{align*} \]

B. A cross between two plants that breed true for different forms of a trait produces F\(_1\) offspring that are identically heterozygous.
Phenotype Ratios in a Monohybrid Experiment

A cross between the F₁ offspring is the monohybrid experiment. The phenotype ratio of F₂ offspring in this example is 3:1 (3 purple to 1 white).
Segregation of Alleles at a Gene Locus

- **Homozygous Dominant Parent**
  - Chromosomes duplicated before meiosis
  - Meiosis I
  - Meiosis II
  - (Gametes)
- **Homozygous Recessive Parent**
  - (Gametes)
  - Fertilization produces heterozygous offspring

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Mendel’s Law of Segregation

- Mendel observed a phenotype ratio of 3:1 in the F$_2$ offspring of his monohybrid crosses
  - Consistent with the probability of the $aa$ genotype in the offspring of a heterozygous cross (Aa x Aa)

- This is the basis of Mendel’s law of segregation
  - Diploid cells have pairs of genes on pairs of homologous chromosomes
  - The two genes of each pair separate during meiosis, and end up in different gametes
Testcrosses

- **Testcross**
  - A method of determining if an individual is heterozygous or homozygous dominant
  - An individual with unknown genotype is crossed with one that is homozygous recessive \((AA \times aa)\) or \((Aa \times aa)\)
Applying Mendel’s Principles

- Mendelian genetics is based on **probability** = the likelihood that an event would occur
Punnett Squares

- **Punnett squares** = a diagram that uses probability to predict the possible genotype and phenotype combination in crosses

T = tall

t = small

(choose a letter from the dominant allele)
For each example, write the genotype and phenotype.

1) The Rr flower
Genotype ____________
Phenotype ____________

2) The rr flower
Genotype ____________
Phenotype ____________
Monohybrid cross

In peas, yellow seeds are dominant to green.

Complete the following cross Yy x yy

1) Make a key — yellow = ____
   green = ____

2) Parental genotypes — if not given
   yy x Yy

3) Set up the Punnett square

4) Figure out the phenotypic and genotypic ratio
   Phenotypic ratio - _________________________________
   Genotypic ratio - _________________________________

Phenotypic ratio - 1 yellow : 1 green

Genotypic ratio - 1 Yy : 1 yy
11.3 Mendel’s Law of Independent Assortment

- Mendel’s law of *independent assortment*

  - Many genes are sorted into gametes independently of other genes

Image:

- a. Chromosome alignments at metaphase I:

  - One of two possible alignments

- b. The resulting alignments at metaphase II:

- c. Possible combinations of alleles in gametes:
Dihybrid cross

- When there are 2 traits it is a **dihybrid cross**.
- Genes for different traits can segregate independently during the formation of gametes.
EXAMPLE PROBLEM

Cross two plants that are heterozygous for height and pod color. Tall is dominant to short and green pods are dominant to yellow

Step 1 – Make a key and determine the parents

Tall =  T  Green =  G

Short =  t  Yellow =  g

Step 2 – Write the genotypes of the parents

TtGg  x  TtGg
Dihybrid cross

**Step 3** – Determine the possible allele combinations for the gametes

**Step 4** – Set up the 16 square Punnett square
Dihybrid cross example

**Step 5** – Complete the Punnett square

![Punnett square diagram](image)

**Step 6** – Determine the phenotypic ratio

9 tall green: 3 tall yellow: 3 short green: 1 short yellow
A Meiosis in homozygous individuals results in one kind of gamete.

B A cross between plants homozygous for two different traits yields one possible combination of gametes:

```
AABB
```

```
AB \times ab
```

```
aabb
```

parent plant homozygous for purple flowers and long stems

parent plant homozygous for white flowers and short stems
**F₁ generation**

All F₁ offspring are AaBb, with purple flowers and tall stems.

**C** Meiosis in AaBb dihybrid plants results in four kinds of gametes:

\[ AB, Ab, aB, ab \]

**F₂ generation**

These gametes can meet up in one of 16 possible ways when the dihybrids are crossed (AaBb \( \times \) AaBb):
Out of 16 possible genetic outcomes of this dihybrid cross, 9 will result in plants that are purple-flowered and tall; 3, purple-flowered and short; 3, white-flowered and tall; and 1, white-flowered and short. The ratio of phenotypes of this dihybrid cross is 9:3:3:1.
Mendel’s Law of Independent Assortment

- Mendel’s dihybrid experiments showed that “units” specifying one trait segregated into gametes separately from “units” for other traits.

- Exception: Genes that have loci very close to one another on a chromosome tend to stay together during meiosis.
In moose, brown coat color (B) is dominant to albino (no pigment) (b) and rough coat (R) is dominant to smooth coat (r). A homozygous brown, homozygous rough male moose mates with a albino, smooth female.

Draw Punnett squares and determine the expected phenotypic ratios for the:

- a) F1 generation
- b) F2 generation
- c) cross between an F1 moose and a moose with the genotype BBRr
a) F1 generation  = 100% BbRr = 100% Brown, rough
b) F2 generation  =  
9 brown rough: 3 brown smooth: 3 albino rough: 1 albino smooth
c) cross between an F1 moose and a moose with the genotype BBRr  
= BBRr x BbRr = 3 Brown rough:1 brown smooth