Genetics Notes

Vocabulary
- Genetics – the study of heredity
- Heredity – the study of characteristics that are inherited from parents
- Fertilization – occurs in sexual reproduction when male and female reproductive cells join and produce a new cell that develops into an embryo
- Trait – specific characteristics – vary from individual to another – Mendel studied 7 traits in pea plants
- Gametes are always haploid
- Gene – chemical factors that determine a trait
- Allele – different forms of a gene (ex. Gene for hair color – there are different alleles that determine whether hair will be brown, blonde, red)
- P – symbol for the original pair of parent plants (or other organism) – Parental
- F1 – symbol for the first set of offspring from the P generation
- Hybrid – offspring of crosses between parents with different characteristics

Gregor Mendel – Father of Genetics
- Identified many rules of heredity (rules which determine how traits are passed from one generation to the next
- Observed that living things pass traits by “something” to the next generation – “something” is genes
- Realized traits could skip a generation – recessive traits (masked by dominant traits)
- Showed traits pass from parents to offspring in a predictable way

Experiments with Pea Plants –
- Normally self-pollinate (sperm pollinates the same plant that produces it)
- True-breeding – occurs when plants self-pollinate and produce offspring identical to the parent plant
- Basis for Mendel’s work
  o He decided to cross pollinate – fertilize sperm and egg from different plants and observe results
  o When he crossed two different pea plants, the characteristics in the offspring did not blend – the offspring only showed one character of one of the parent plants.
  o P generation: Tall x Tall → Tall (F1)
  o P generation: Tall x Short → Tall (f1) → (not a blend of the two)
  o F1 offspring (tall) x F1 offspring (tall) → 3 tall, 1 short

Mendel’s findings
1. Individual units known as genes determine the inheritance of characteristics. Genes are passed on from one generation to the next
2. Law of Dominance: When there are two or more alleles for a single trait, some forms of the gene may be dominant and others recessive.
3. Law of Segregation: in most sexually reproducing organisms, adults have two copies of each gene. The genes are segregated during meiosis and gametes are formed.
4. Law of Independent Assortment: the alleles for different genes are usually segregated independently of one another during gamete formation.
5. Recessive forms are only exhibited when the dominant allele is not present

Probability – the likelihood that an event will occur
**Punnett Squares** – method for showing the possible genotypes and phenotypes two individuals can produce when crossed and the probability of each

**Definitions**

- **Genotypes** – the genetic make-up of an organism – shown by using letters
  - T – capital letters represent dominant alleles
  - t – lower case letters represent recessive alleles
- **Phenotype** – what you can see and describe
  - physical characteristics exhibited by an organism – eye color, hair color
- **Homozygous** – organisms that have two identical alleles for a particular trait (TT or tt)
- **Heterozygous** – organisms that have two different alleles for a particular trait (also called hybrid) - Tt

Determining parental genotypes in various word problems:

In humans, tongue rolling (T) is dominant over non-rolling (t).

Examples:

<table>
<thead>
<tr>
<th>Given</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homozygous (Pure) dominant</td>
<td>TT</td>
</tr>
<tr>
<td>Heterozygous (Hybrid) dominant</td>
<td>Tt</td>
</tr>
<tr>
<td>Tongue rolling – homozygous</td>
<td>TT</td>
</tr>
<tr>
<td>Tongue rolling – heterozygous</td>
<td>Tt</td>
</tr>
<tr>
<td>Non-rolling</td>
<td>tt – must both be lower for recessive trait to be exhibited</td>
</tr>
</tbody>
</table>

Example: Let’s identify parts of the following Punnett square:

- Which squares in the box are homozygous?
- Which squares in this box are heterozygous?
- Which alleles represent the parents – P generation? Outside the box
- Which alleles represent the offspring - F1 generation? Inside the box

What is the probability the offspring will be have two TT alleles, Tt alleles, tt alleles?
- count the number of boxes with the genotype
- divide by the total number of boxes (4)
- then, multiply by 100

**Genotypic Ratios and % (genetic make-up of organism)**

<table>
<thead>
<tr>
<th></th>
<th>TT</th>
<th>Tt</th>
<th>tt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>1:4</td>
<td>2:4</td>
<td>1:4</td>
</tr>
<tr>
<td>1:2 (simplified)</td>
<td>1:2:1</td>
<td>(first number from each simplified ratio)</td>
<td></td>
</tr>
<tr>
<td>Percent:</td>
<td>25%</td>
<td>50%</td>
<td>25%</td>
</tr>
</tbody>
</table>

**Phenotypic Ratios and %**

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Tall (TT, Tt)</th>
<th>Short (tt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>3:4</td>
<td>1:4</td>
</tr>
<tr>
<td>Percentage</td>
<td>75%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Note: short will only be exhibited when 2 recessive alleles are present
Gene Expression

Given the following genotypes, list the genetically different gametes that can result?

AA – A, A
AABB – AB
AaBB – AB, aB
AaBb – AB, Ab, aB
AaBBcDd – ABCD, ABcD, aBCD, aBcD, aBD, aBCD

General rule for determining the number of different gametes organisms can produce is

Number of different gametes after meiosis = $2^n$, where $n$ = number of heterozygous alleles (genes).

Steps for Completing Punnett Squares:

Monohybrid Cross: one trait is being studied

Example: In humans, being a tongue roller (R) is dominant over non-roller (r). A man who is a non-roller marries a woman who is heterozygous for tongue rolling.

Step 1: identify dominant and recessive alleles and assign letters (be sure to choose letters where the capital and lower case look different)

Dominant – tongue roller - R
Recessive – non-roller – r

Step 2: Identify parental genotypes:

Man – non-roller – since this is the recessive trait he must be homozygous recessive – rr
Woman – heterozygous for tongue rolling – Rr

Step 3: Set up Punnett square with parental gametes (alleles) outside the box.

<table>
<thead>
<tr>
<th>Man’s alleles</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
</tr>
<tr>
<td>r</td>
</tr>
</tbody>
</table>

Step 4: Fill in offspring boxes by carrying parental alleles down and across boxes.
Step 5: Determine genotypic and phenotypic ratios

Genotypic:

To determine ratio: total number of times allele combination is present in Punnett square compared to total number of boxes in Punnett square. Ex. Rr is present in 2 boxes out of 4 → 2:4

This can be simplified to 1:2

To determine percentage: total number of times allele combination is present in Punnett square divided by total number of boxes in Punnett square x 100

Ex. rr is present in 2 boxes out of 4 → 2 divided by 4 times 100 = 50%

<table>
<thead>
<tr>
<th></th>
<th>Rr</th>
<th>rr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>2:4</td>
<td>2:4</td>
</tr>
<tr>
<td>Ratio (simplified)</td>
<td>1:2</td>
<td>1:2</td>
</tr>
<tr>
<td>Overall ratio</td>
<td>1:1</td>
<td>(same possibility for each)</td>
</tr>
<tr>
<td>Percentage</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Phenotypic:

To determine ratios: total number of times trait is exhibited out of total number of boxes in Punnett square.

<table>
<thead>
<tr>
<th></th>
<th>Tongue roller</th>
<th>Non-roller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>2:4</td>
<td>2:4</td>
</tr>
<tr>
<td>Ratio (simplified)</td>
<td>1:2</td>
<td>1:2</td>
</tr>
<tr>
<td>Overall ratio</td>
<td>1:1</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>
Dihybrid Cross Notes

Dihybrid Cross - a cross between two different parents with two observed traits

Step 1: Determine letters you will use to specify traits. Each trait will be represented by a different letter. Be sure to choose letters in which the capital and lower case look different.

Step 2: Determine parent’s genotypes. – same rules as monohybrid (4 letters due to 2 traits)

- Homozygous dominant – two capital letters for the trait
- Homozygous recessive – two lower case letters for the trait
- Heterozygous – one capital letter, one lower case letter

Be sure to keep the letters representing each trait together – TtFf, not TFtf

Step 3: Determine parent’s alleles.

- First – the first of each letter shown
- Outside - the two letters on the outside
- Inside – the two letters in the middle
- Last – the second (last) of each letter shown

STEP 4: Make your Punnett square, complete cross and determine possible offspring.

STEP 5: Determine genotypic and phenotypic ratios.

Example: Set up a Punnett square using the following information:

Tall plants are dominant to short plants and purple flowers are dominant to white.

Step 1: T = tall plant, t = short plant  
F = purple flowers, f = white flowers

Note: dominant form of each trait has different capital letter and recessive forms have the corresponding lower case letter just as in a monohybrid problem.

Step 2: Parental genotypes

- Parent 1: Homozygous dominant for height and heterozygous for color  
  TTFf
- Parent 2: Homozygous recessive parent  
tfff

Step 3: Using FOIL, determine parental alleles:

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>O</th>
<th>I</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent 1:</td>
<td>TF</td>
<td>Tf</td>
<td>TF</td>
<td>Tf</td>
</tr>
<tr>
<td>Parent 2:</td>
<td>tf</td>
<td>tf</td>
<td>tf</td>
<td>tf</td>
</tr>
</tbody>
</table>

Step 4: Complete Punnett Square:
### Step 5:

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TtFf 8:16  50%</td>
<td>Tall, Purple Flowers  8:16  50%</td>
</tr>
<tr>
<td>Ttff 8: 16  50%</td>
<td>Tall, White Flowers   8:16  50%</td>
</tr>
</tbody>
</table>

|  |  | | | |
|---|---|---|---|
| tf | TtFf | Ttff | TtFf | Ttff |
| tf | TtFf | Ttff | TtFf | Ttff |
| tf | TtFf | Ttff | TtFf | Ttff |
| tf | TtFf | Ttff | TtFf | Ttff |
Incomplete Dominance Traits

**Incomplete Dominance** – a cross between organisms with two different phenotypes which produces offspring with a third phenotype that is a blending of the parental traits.

Example: Red Flower x White Flower → Pink Flower

In this example, red does not totally block (dominate) the white; so, instead there is incomplete dominance, and we end up with something in-between – pink.

We still use a Punnett Square to solve problems involving incomplete dominance. The only difference is we only use capital letters because neither trait is dominant.

How to tell if a problem is an incomplete dominance problem:

1) Notice the offspring have a third phenotype with the parents each having one.
2) Notice that the offspring’s trait is a blend of the parental traits.

Sample problem: A cross between a blue blahblah bird and a white blahblah bird produces offspring that are silver. The color of blahblah birds is determined by just two alleles.

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>BW</td>
<td>BW</td>
</tr>
<tr>
<td>W</td>
<td>BW</td>
<td>BW</td>
</tr>
</tbody>
</table>

Step 1: Determine letters for genotypes:

BB – blue  WW – white  BW – silver

Step 2: Complete Punnett Square

Step 3: Genotypic and Phenotypic Ratios

Genotype:  BW – 4:4  1:1  100%

Phenotype:  Pink – 4:4  1:1  100%
Co-dominance Traits

“Co” means together; Codominance is similar to incomplete dominance; except, in co-dominance, the two traits appear together in the phenotype of the offspring.

Example: Red Flower x White Flower → Red and White Spotted Flowers

How to tell if a problem is an incomplete dominance problem:

1) Notice the offspring have a third phenotype with the parents each having one.
2) Notice that the offspring’s trait exhibits both of the parental traits.

Sample problem: A cross between a red flower and a white flower produces offspring that are red and white spotted.

Step 1: Determine letters for genotypes:

<table>
<thead>
<tr>
<th></th>
<th>F_R</th>
<th>F_W</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_R</td>
<td>red</td>
<td>F_WF_R – white</td>
</tr>
</tbody>
</table>

Step 2: Complete Punnett Square

<table>
<thead>
<tr>
<th></th>
<th>F_R</th>
<th>F_R</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_W</td>
<td>F_WF_R</td>
<td>F_WF_W</td>
</tr>
<tr>
<td>F_W</td>
<td>F_WF_W</td>
<td>F_WF_W</td>
</tr>
</tbody>
</table>

Step 3: Genotypic Phenotypic Ratios

Genotype: F_RF_W – 4:4 1:1 100%

Phenotype: Red and White Spotted - 4:4 1:1 100%