Mendel's Laws: Human Inheritance of Single Gene Traits

A Brief Review of Mendel's Work with Garden Pea Plants

In garden pea plants, there are two character states for pea height, tall and short. Mendel began with pure lines of pea plants. In plants, **pure lines** are strains that consistently yield offspring with the same traits generation after generation. Mendel grew plants that were of pure line for tall and plants that were of pure line for short. He crossed a pure line tall parent plant with a pure line short parent plant (the **P generation**) to produce hybrids (the **F_1 generation** [first filial], in simple terms, the children of the parent plants). He then obtained a second hybrid generation (the **F_2 generation** [second filial], in simple terms, the grandchildren of the parent plants) by crossing the F_1 generation plants with each other. The following results were observed…

	Crossing	Results
1st cross	pure line tall X pure line short	100% tall hybrids (children of the pure line parent plants that were as tall as the parent plant)
2nd cross	hybrid tall F_1 X hybrid tall F_1	¾ tall to ¼ short plants (the grandchildren of the pure line parent plants)

Mendel made the following conclusions…

1. **Alleles** control an inherited characteristic & exist in individuals in pairs (You inherit one member of the pair from your father & one member of the pair from your mother). The two alleles of a pair are the same in **homozygous** individuals (e.g. the pure line short plants are homozygous for the character state of short. Their allele pair is short/short). The two alleles of the pair differ in **heterozygous** individuals (e.g. the hybrid F_1 generation inherited a tall allele from one parent and a short allele from the other parent. Thus their allele pair is tall/short). The **genotype** is the allele combination that produces a character state. The genotype of the hybrid F_1 generation is tall/short. The **phenotype** is the visible, physical trait. The phenotype of the hybrid F_1 generation is tall.

2. **LAW OF DOMINANCE**: Whenever the two alleles of a pair in a given individual differ, only one, the dominant one will be expressed. In the hybrid F_1 generation, the plants inherited one tall allele and one short allele. Yet, all of these plants appeared to be tall. Thus tall is the **dominant allele** (the allele that indicates the appearance of heterozygotes). One allele is said to be dominant over another if a heterozygous individual for that allele has the same appearance as an individual homozygous for it. The short allele is the **recessive allele** (an allele whose phenotype effects are masked in heterozygotes by the presence of a dominant allele).

3. **LAW OF SEGREGATION OF ALLELES**: When the gametes (egg & sperm) are formed by an individual, only one member of each allele pair is included in a gamete. Recall that gametes are **haploid**. When the hybrid F_1 generation plants produce gametes, each gamete will receive only one allele for plant height. So, an egg (or a sperm) will have an allele for tall or an allele for short, but not both. When the egg unites with the sperm during **fertilization**, the sperm will carry one allele for plant height, restoring the allele pair and the **diploid** condition.

4. **LAW OF INDEPENDENT ASSORTMENT**: All of the possible kinds of gametes that can be formed, will be formed in equal proportions. Alleles for different traits are inherited independently of each other if they are located on different homologous gene pairs.

If Mendel had a tall pea plant, how could he be certain that it was a pure line tall plant? ____
____

The Sad Plight of the Naked Bunnies

Photo source: users.tamuk.edu/kfsdl00/rabb.html

In this activity, you will examine inheritance in a small population of wild rabbits. Breeders of rabbits have long been familiar with a variety of genetic traits that affect rabbits. One such trait is the trait for furless rabbits (naked bunnies, you can imagine their embarrassment). This trait was first discovered in England by W.E. Castle in 1933. The dominant allele is for normal fur. The recessive allele is for no fur. Bunnies that inherit two alleles for fur OR one allele for fur and one allele for no fur will have fur, while bunnies that inherit two alleles for no fur will have no fur.

Exploring Segregation (the production of gametes)

In this exercise, we are going to imagine that we crossed a pure line furred rabbit with a naked rabbit. This cross produced 10 hybrid bunnies that were furred, but carried the recessive allele. So, from the hybrid F_1 (hybrid) generation of bunnies, we will have a total of 10 alleles for fur and 10 alleles for no fur.

We are going to simulate this situation by placing 10 white beads (representing the furred allele) & 10 red beads (representing the furless allele) into a cup. We will draw one bead at a time from the cup, without looking, to produce a "gamete" & then return the bead to the gene pool. Repeat the process of picking a bead out of the cup & returning it for the number of times indicated by your instructor. Each time, record in Table 1 whether the chosen bead is red or white. When you have completed your table, add your results to those of other members of the class in the table on the chalkboard.

Table 1. "Gametes"

	WHITE	**RED**
Your Total		
Class Total		

When we do this, we have a one in two (or 50%) chance of drawing a white bead and a one in two (or 50%) chance of drawing a red bead. Let's imagine that we drew 200 times at random from the cup. We would expect to form 100 gametes with the furred (white) allele and 100 gametes with the naked (red) allele.

Does one always get exactly the fraction expected in gamete production? _____

What could one do to get closer to the expected ratio?
____
____

Do a larger number of choices (the pooled data of the class) more closely approach what is expected? ____

In a bunny with one allele for fur and one allele for furless (a heterozygous bunny), what fraction of the gametes should contain the fur allele? ________

Exploring Fertilization

In this exercise, we will work in pairs. Each partner will represent on hybrid F_1 generation bunny capable of producing gametes with furred (white) alleles and gametes with furless (red) alleles. One partner will produce the eggs (by drawing one bead from the cup) and the other partner will produce the sperm (by drawing one bead from the cup). We will use the cup with 10 red beads and 10 white beads, as before. Each time you draw, you are simulating the union of one egg and one sperm, resulting in the formation of one offspring. You and your partner should each pick one bead from the cup as often as your instructor indicates. Return the two beads to the cup after each pick & record the red/red, red/white, and white/white combinations in Table 2. Again, the class results will be tabulated on the chalkboard. Since in the offspring it usually makes no difference whether the one allele (white) comes from the male parent or form the female parent, the two different red/white or white/red combinations are recorded together.

Table 2. "Genotypes"

	WHITE / WHITE	**WHITE / RED**	**RED / RED**
Your Results			
Class Totals			

In this procedure, you & your partner each have a 50% chance of drawing a red bead and a 50% chance of drawing a white bead. Every time you both draw, there are four possible outcomes.

1. **Partner 1 might draw a white bead. Partner 2 might draw a white bead**. This would produce a homozygous dominant (or furred) rabbit. The probability of this happening can be obtained by multiplying the chance of the first event occurring by the chance of the second event occurring. In other words…

(50% chance of Partner 1 drawing white)(50% chance of Partner 2 drawing white) = **25% chance** of offspring inheriting **white / white**, or both alleles for the furred condition.

2. **Partner 1 might draw a white bead. Partner 2 might draw a red bead.** This would produce a heterozygous rabbit that would be furred. The probability of this happening is…
(50% chance of Partner 1 drawing white)(50% chance of Partner 2 drawing red) = 25% chance of offspring inheriting white / red, or one allele for the furred condition and one allele for furless condition.

3. **Partner 1 might draw a red bead. Partner 2 might draw a white bead.** This would produce a heterozygous rabbit that would be furred. The probability of this happening is…
(50% chance of Partner 1 drawing red)(50% chance of Partner 2 drawing white) = 25% chance of offspring inheriting red / white, or one allele for the furred condition and one allele for furless condition.

Note that outcomes 2 & 3 can be combined because it doesn't matter whether the rabbits inherit the allele for fur from the mother or the father, it still produces a heterozygous rabbit that would be furred. Thus, the chance of producing a heterozygous offspring is 25% + 25% = **50% chance of white / red**

4. **Partner 1 might draw a red bead. Partner 2 might draw a red bead.** This would produce a homozygous furless or naked bunny. The probability of this happening is…
(50% chance of Partner 1 drawing red)(50% chance of Partner 2 drawing red) = **25% chance** of offspring inheriting **red / red**, or both alleles for the furless condition and one allele for the furless condition.

Imagine that we drew 200 times (representing the production of 200 baby bunnies). We could predict that 25% or 50 of the offspring would inherit white / white, 50% or 100 of the offspring would inherit white / red, and 25% or 50 of the offspring would inherit red / red. This would give us a **genotypic ratio** of 50 white / white : 100 white / red : 50 red / red. We could simplify this as 1 homozygous furred : 2 heterozygous furred : 1 homozygous furless.

In the above situation, we know that furred is dominant to furless. Thus, of the 200 offspring we created, we would expect 150 to be furred and 50 to be furless. This would give us a **phenotypic ratio** of 150 furred : 50 furless. We could simplify this as 3 furred : 1 furless.

Using the genotype data from Table 2, transfer the allele combination to Table 3 that represents the phenotypes of our bunnies.

Table 3. "Phenotypes"

	FURRED (white / white or white / red)	**FURLESS** (red / red)
Your Results		
Class Results		

What ratio of furred to furless did you and your partner get? ___________________________

How does the expected F_2 fur ratio compare to the data you obtained here?____
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How does the pooled data of the class compare to your data for the expected F_2 ratio?
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Is the dominant or recessive trait more frequent in an F_2 generation?
____
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Human Inheritance of Single Gene Traits

Determine your own phenotype for each of the following traits. For some of the more easily observed traits you may be able to recall the phenotypes of your parents. If it is possible, determine your own genotype by comparing phenotypes of your parents and your own phenotype. If you have the dominant phenotype, give both possibilities for your genotype where it cannot be determined definitely. Record your phenotypes in Table 4 and on the chalkboard so that the data of the entire class may be tabulated. Record in your table the class results.

Table 4. Tabulation of Human Traits

GENETIC TRAITS		YOUR RESULTS		CLASS TABULATION	
Phenotype	**Genotype**	**Phenotype**	**Genotype**	**# Dominants**	**# Recessives**
PTC taster Nontaster	PP or Pp pp				
Thiourea Supertaster Medium taster Nontaster	TT Tt tt				
Sodium Benzoate taster Non taster	SS or Ss ss				
Double-jointed thumb Tight joints	JJ or Jj jj				
Widow's Peak Straight hair line	WW or Ww ww				
Curly hair Wavy hair Straight hair	CC CC' C'C'				
Nonred hair Red hair	NN or Nn nn				
Dark hair Blond hair	MM or Mm mm				
Freckles No freckles	FF or Ff ff				
Cheek dimple No cheek dimple	DD or Dd dd				
Free earlobes Attached earlobes	EE or Ee ee				
Tongue rolling present Tongue rolling absent	RR or Rr rr				
Digital hair present Digital hair absent	MM or Mm mm				
Straight thumb Hitchhikers's thumb	HH or Hh hh				
Left thumb over right Right thumb over left	LL or Ll ll				
Bent little finger Straight little finger	BB or Bb bb				
Cleft chin present Absence	CC or Cc cc				
Unibrow Separate eyebrows	UU or Uu uu				

For how many traits are you recessive? ______________________

On the basis of the tabulated results for the entire class, are there any recessive traits which are more common among the class members than the dominant condition? If so, name them.

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What difference would you expect in the tabulation if 1000 students were included in the table?

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