English language for agricultural majors

Dr. Sayed Gebril

Lecture 7 & 8

UNIT 8 -GREGOR MENDEL AND THE PRINCIPLES OF INHERITANCE

Gregor Mendel's **principles of inheritance** form the corner stone of **modern genetics**. So just what are they?

Ever wonder why you are the only one in your family with your grandfather's nose? The way in which **traits** are passed from one **generation** to the next-and sometimes **skip generations** - was first explained by Gregor Mendel.

By experimenting with pea **plant breeding**, Mendel developed three **principles of inheritance** that described the **transmission of genetic traits**, before anyone knew **genes** existed. Mendel's insight greatly expanded the understanding of **genetic inheritance**, and led to the development of new experimental methods.

Mendel was curious about how traits were transferred from one generation to the next, so he set out to understand the **principles of heredity** in the mid-1860s. Peas were a good **model system**, because he could easily control their fertilization by transferring pollen with a small paint brush. This pollen could come from the same flower (**self-fertilization**), or it could come from another plant's flowers (**cross-fertilization**).

First, Mendel observed plant **forms** and their **offspring** for two years as they **self-fertilized**, or "**selfed**," and ensured that their **outward**, **measurable characteristics** remained constant in each generation. During this time, Mendel observed seven different characteristics in the pea plants, and each of these characteristics had two **forms** (Figure1).

The characteristics included **height** (**tall** or **short**), **pod shape** (**inflated** or **constricted**), **seed shape** (**smooth** or **wrinkled**), **pea color** (green or yellow), and so on. In the years Mendel spent letting the plants self, he verified the **purity** of his plants by confirming, for example, that tall plants had only tall children and grandchildren and so forth.

Because the seven pea plant characteristics tracked by Mendel were consistent in generation after generation of self-fertilization, these **parental lines** of peas could be considered **pure-breeders** or pure lines (or, in modern terminology, **homozygous** for the traits of interest).

Understanding **dominant traits**

Before Mendel's experiments, most people believed that traits in offspring resulted from a blending of the traits of each parent. However, when Mendel **cross-pollinated** one variety of **purebred** plant with another, these crosses would yield offspring that looked like either one of the parent plants, not a **blend** of the two.

For example, when Mendel cross-fertilized plants with **wrinkled seeds** to those with **smooth seeds**, he did not get **progeny** with semi-wrinkly seeds. Instead, the progeny from this cross had only smooth seeds. In general, if the progeny of crosses between purebred plants looked like only one of the parents with regard to a specific trait, Mendel called the expressed parental trait the **dominant trait**.

From this simple observation, Mendel proposed his first principle, **the principle of uniformity**; this principle states that all the progeny of a cross like this (where the parents differ by only one trait) will appear identical.

When conducting his experiments, Mendel designated the two pure-breeding parental generations involved in a particular cross as **P_1** and **P_2**, and he then denoted the progeny resulting from the crossing as the **filial**, or **F_1**, generation. Although the plants of the **F_1 generation** looked like one parent of the **P generation**, they were actually **hybrids** of two different parent plants.

Upon observing the uniformity of the F_1 generation, Mendel wondered whether the F_1 generation could still possess the **non dominant** traits of the other parent in some hidden way.

To understand whether traits were hidden in the F_1 generation, Mendel returned to the method of self-fertilization. Here, he created an **F_2 generation** by letting an F_1 pea plant self-fertilize (F_1 x F_1).

This way, he knew he was crossing two plants of the exact same genotype. This technique, which involves looking at a single trait, is today called a **monohybrid cross**. The resulting F_2 generation had seeds that were either round or wrinkled. Figure 2 shows an example of Mendel's data. The result of the experiment shows that the single characteristic of seed shape was expressed in two different forms in the F_2 generation: either round or wrinkled.

Also, when Mendel averaged the relative proportion of round and wrinkled seeds across all F_2 progeny sets, he found that round was consistently three times more frequent than wrinkled. This 3:1 proportion resulting from F_1 x F_1 crosses suggested there was a hidden **recessive** form of the trait. Mendel recognized that this recessive trait was carried down to the F_2 generation from the earlier P generation.

Mendel and Alleles

Mendel **hypothesized** that each parent contributes some **particulate matter** to the offspring. He called this heritable substance **"elementen."**(Remember, in 1865, Mendel did not know about DNA or genes.) Indeed, for each of the traits he examined, Mendel focused on how the elementen that determined that trait was distributed among progeny. We now know that a single gene controls seed form, while another controls color, and so on, and that **elementen** is actually the assembly of physical genes located on **chromosomes**. **Multiple forms** of those genes, known as **alleles**, represent the different traits. For example, one allele results in **round seeds** and another allele specifies **wrinkled seeds**. Mendel's notation of a capital and a lowercase letter (*Aa*) for the hybrid genotype actually represented what we now know as the two alleles of one gene: *A* and *a*.

When one parent carried all the **dominant traits** (*AA*), the F_1 hybrids were "**indistinguishable**" from that parent.

However, even though these F_1 plants had the same phenotype as the **dominant P_1 parent**, they possessed a **hybrid genotype** (*Aa*) that carried the potential to look like the **recessive P_1parent** (*aa*).

After observing this potential to express a trait without showing the phenotype, Mendel put forth his second principle of inheritance: **the principle of segregation**. According to this principle, the **"particles"** (or alleles as we now know them) that determine traits are separated into gametes during **meiosis**, and meiosis produces equal numbers of **egg** or **sperm** cells that contain each allele (Figure 3).

Dihybrid Crosses

Mendel had thus determined what happens when two plants that are hybrid for one trait are crossed with each other, but he also wanted to determine what happens when two plants that are each hybrid for two traits are crossed. Mendel therefore decided to examine the inheritance of two characteristics at once. Based on the concept of segregation, he predicted that traits must sort into gametes separately.

By extrapolating from his earlier data, Mendel also predicted that the inheritance of one characteristic did not affect the inheritance of a different characteristic. Mendel tested this idea of **trait independence** with more complex crosses. First, he generated plants that were purebred for two characteristics, such as seed color (yellow and green) and seed shape (round and wrinkled).

These plants would serve as the P_1 generation for the experiment. In this case, Mendel crossed the plants with wrinkled and yellow seeds (*rrYY*) with plants with round, green seeds (*RRyy*). From his earlier monohybrid crosses, Mendel knew which traits were dominant: round and yellow.

So, in the F_1 generation, he expected all round, yellow seeds from crossing these purebred varieties, and that is exactly what he observed. Mendel knew that each of the F_1 progeny were **dihybrids**; in other words, they contained both alleles for each characteristic (*RrYy*). He then crossed individual F_1 plants (with genotypes *RrYy*) with one another. This is called a dihybrid cross.

Mendel's results from this cross were as follows:

315 plants with round, yellow seeds

108 plants with round, green seeds

101 plants with wrinkled, yellow seeds

32 plants with wrinkled, green seeds

Thus, the various phenotypes were present in a 9:3:3:1 ratio.Next, Mendel went through his data and examined each characteristic separately. He compared the total numbers of round versus wrinkled and yellow versus green peas, as shown in Tables 1& 2.

Table 1: Data Regarding Seed Shape

Round: Wrinkled

Number of plants: 315 + 108 = 423, 101 + 32 = 133

Proportion of total, 3.2: 1

Table 2: Data Regarding Pea Color (Yellow: Green)

Number of plants: 315 + 101 = 416, 108 + 32 = 140

Proportion of total

2.97: 1

The proportion of each trait was still approximately 3:1 for both seed shape and seed color. In other words, the resulting seed shape and seed color looked as if they had come from two parallel monohybrid crosses;

even though two characteristics were involved in one cross, these traits behaved as though they had **segregated independently**. From these data, Mendel developed the **third principle of inheritance**: **the principle of independent assortment**. According to this principle, **alleles** at one **locus** segregate into gametes independently of alleles at other **loci**. Such **gametes** are formed in **equal frequencies**.

But do all organisms pass on their genes in the same way as the garden pea plant? The answer to that question is no, but many organisms do indeed show inheritance patterns similar to the seminal ones described by Mendel in the pea. In fact, the three principles of inheritance that Mendel laid out have had far greater impact than his original data from pea plant manipulations. To this day, scientists use Mendel's principles to explain the most basic phenomena of inheritance

Exercise A *Punnet square (predicting the outcomes)*

purple ***Pp***	*purple* ***Pp***
purple ***Pp***	*purple* ***Pp***

Punnett square is an illustration square first described by the scientist Punnett to solve the Mendelian genetic problem and an easy way to predict the outcome of simple genetic crosses (mono and dihybrids).

EXAMPLE

A homozygous pea plant with purple flower was mated to a homozygous pea plant with white flower . Purple color is dominant to white color. Using the Punnett square, give the genotypes and phenotypes for F1 and F2 progenies.

The red plant will be designated (*PP*)

the white plant will be designated (*pp)*

EXAMPLE

Purple flower

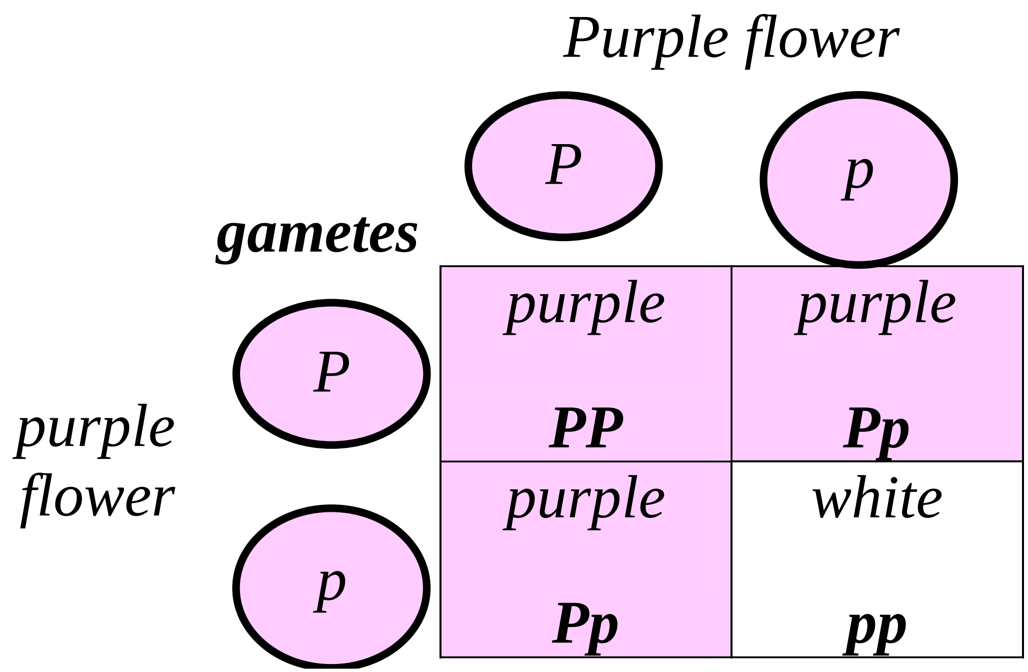
White flower

gametes	*P*	*P*
p	*purple* ***Pp***	*purple* ***Pp***
p	*purple* ***Pp***	*purple* ***Pp***

All the offspring in the F1 (first filial generation) are purple and heterozygous (*Pp*).

EXAMPLE

In the F2 (second filial generation) , the pea plant will be self-fertilized (selfed) and by using Punnett square the progeny will be as following



Two phenotypes; purple flower and white flower

Three genotypes; dominant homozygous (*PP*) ,heterozygous (*Pp*) and recessive heterozygous (*pp*).

EXERCISE A

Now solve the following problem using Punnett square to predict the outcomes

1- A tall pea (*TT*) was mated to short (dwarf) (*tt*) pea plant. Tall is dominant to dwarf. What are the genotypes and phenotypes in F1 and F2?

2- A heterozygous smooth (round) seed pea plant (Rr)is self-fertilized. Round is dominant and wrinkled is recessive. What are the genotypes and phenotypes in F1?

EXERCISE B

Answer the following questions

1. What are the principles of heredity Mendel proposed?
2. Why did Mendel choose pea to do his experiments?
3. What did Mendel call the gene?
4. Did Mendel proved or disproved the theory of traits blend?

EXERCISE C *definition*

Consult or refer to your text book or the internet to properly difine the following words or phrases using one of definition forms we have learned in this course.

1. dominant allele
2. recessive allele
3. homozygous organism