<u>STUDY GUIDE</u> - *Ch. 14.1 – Mendel Used the Scientific Approach to Identify Two Laws of Inheritance.* **NAME:** ________________________

- **<u>PHYSICALLY PRINT OUT</u> this PDF and <u>HANDWRITE</u> (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **<u>not</u>** accepted. Do **<u>not</u>** answer questions on separate paper.*
- **Importantly, study guides are <u>NOT GROUP PROJECTS</u>!!!** *You, and you alone, are to answer the questions as you **<u>read</u>** your assigned textbook. You are **<u>not</u>** to share answers with other students. You are **<u>not</u>** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing <u>LEGIBLY</u>, neatly, and in a <u>medium-sized font.</u>** *AP essay readers and I will skip grading anything that cannot be easily read so start perfecting your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **<u>SCAN</u> physical documents in color and with good resolution. Then, upload your final work as <u>PDFs</u> to Archie.** *Avoid uploading dark, shaded, washed-out, sideways, or upside-down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **<u>READ FOR UNDERSTANDING</u> and not merely to complete an assignment.** ***<u>First</u>**, read a section quickly to get an overview of the topic covered. Then, read it a **<u>second</u>** time slowly, paraphrasing each paragraph **<u>out loud</u>** and analyzing every figure. Finally, read it a **<u>third</u>** time as you answer the study guide questions if assigned and start building your memory. Try to write answers out in your own words, when possible, and try to purposefully and accurately use all new terminology introduced.*

1. Because of the work of Gregor Mendel in the 1800s, he is referred to today as the *"father of genetics"* even though he did not yet know about the existence of genes on chromosomes, a fact we don't come to understand until the 1900s. Nonetheless, Mendel came up with hypotheses for inheritance that still are valid today. One of the keys to success for Mendel was using pea plants in his studies of inheritance. What are **<u>four advantages of using pea plants</u>**?

   1.

   2.

   3.

   4

2. There are a few key terms that you **<u>need to know well</u>** as we voyage into the work of Gregor Mendel. What do the following terms mean?

   <u>Character</u> =

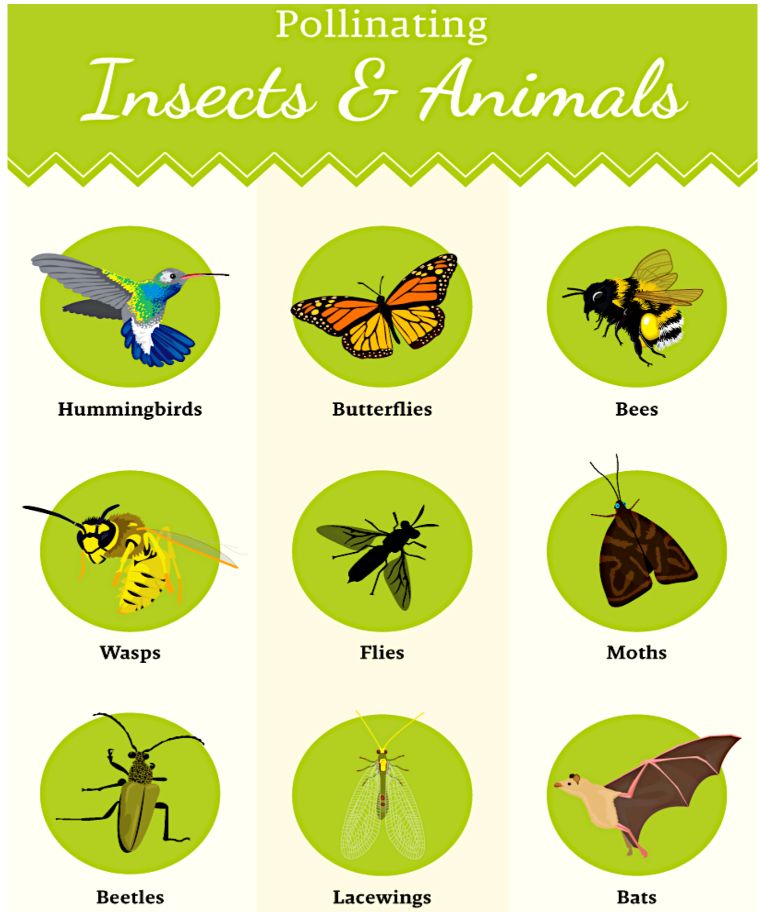
   <u>Trait</u> *(Do **<u>not</u>** mix this up with Character)* **=**

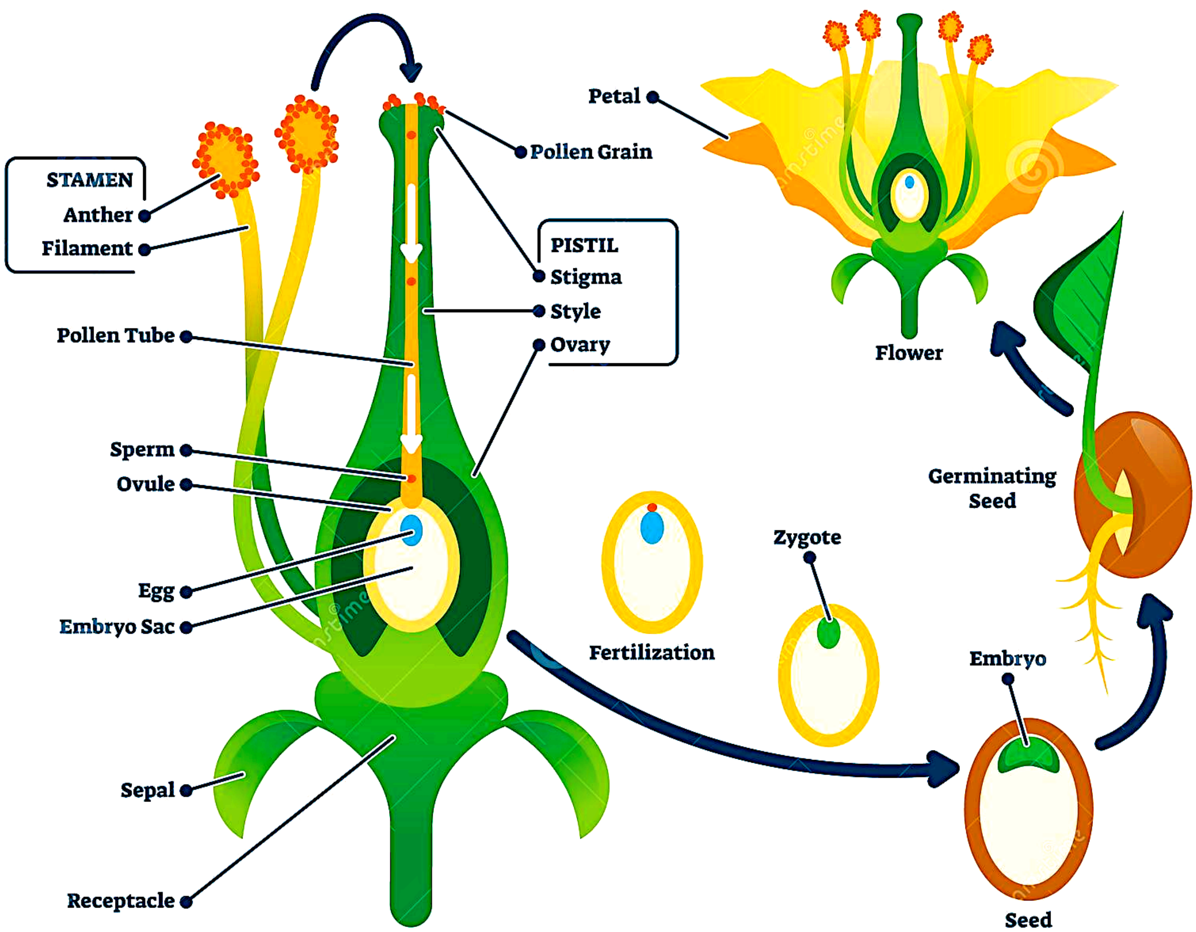
Mendel used Pea Plants as the subject of his heredity studies. Let's learn about flowering plant reproduction: <u>watch and study</u> the following video <u>carefully</u> before proceeding! Memorize the important anatomical parts of flowers and the process by which reproduction in flowering plants occurs - *info you need to know not just for the **AP** exam, but for your Florida state **EOC** exam as well!*

<u>https://www.youtube.com/watch?v=HLYPm2idSTE</u>

Flowers are special structures for reproduction in plants. They contain male parts (**the stamen**) that have regions (**the anther**) that make pollen ***(inside of which the sperm cells will form)*** and they contain female parts (**the carpel or pistil**) that contain **ovaries,** which contain one or more **ovules** ***(inside of which the egg will be made)***. Some plants contain male and female parts in different regions of the same flower while other plant species make two totally different types of flowers, some with only male parts and some with only female parts.

Pollen is carried from a male part (the anther) to a female part (the carpel or pistil) **by wind, water, or** **pollinators** (animals like insects, bats, birds etc...), **which carry the pollen on their bodies from one flower to the next**, a process called **pollination. When pollen lands on the sticky stigma portion of the carpel/pistil, the pollen grain releases male gametes (sperm cells) that fertilize the female gametes in the ovules inside the ovary.** The **ovules develop into seeds** and the **ovary surrounding the ovule develops into fruit** (which can be soft like a cherry or hard like a walnut). The **zygote inside the seed undergoes mitosis to form the new embryo.** Eventually, during the process of **germination**, the embryo, now called a **seedling** (the new offspring plant) grows out of the seed.





3. Mendel chose to trace characters that occurred as only two traits. For the <u>**character** flower color</u>, for example, he noted whether the plant produced the <u>purple vs white flower color **traits**</u>. For the <u>**character** seek shape</u>, for example, he noted whether the plant produced the <u>round vs wrinkled seed shape **traits**</u>. He started his experiments with plants he deemed "true breeders" and used them to produce "hybrids." Explain these terms.

<u>True-breeding</u> =

<u>Hybridization</u> =

<u>P generation</u> =

<u>F_1 generation</u> =

<u>F_2 generation</u> =

4. a. In the 1800s the most widely favored explanation of of how inheritance worked was blending. What was believed by proponents of the **<u>blending hypothesis</u>**.

b. If you started off with a character for which there were many traits, such as a type of plant with flower colors that come in red, blue, and white, what would be the resulting look of this character in this plant species many generations later if the blending hypothesis was accurate and plants with these different traits kept randomly mating together? Explain.

c. Read your text and **<u>review Figure 14.3</u>.** Think about the **<u>two ways the blending hypothesis failed</u>** to account for actual observations Mendel made **<u>in BOTH the F1 and F2 generations</u>** when tracing pea flower color inheritance. *Let's understand what he should have seen in the F1 and F2 plants, if blending occurred, and what he saw instead.*

Had the blending hypothesis been true, what should Mendel have seen in the F_1 generation **<u>AND</u>** in the F_2 generation, and <u>*why*</u>?

1. In the <u>F_1 generation</u>, if the two copies of a character's information obtained **<u>blended</u>** together in an offspring =

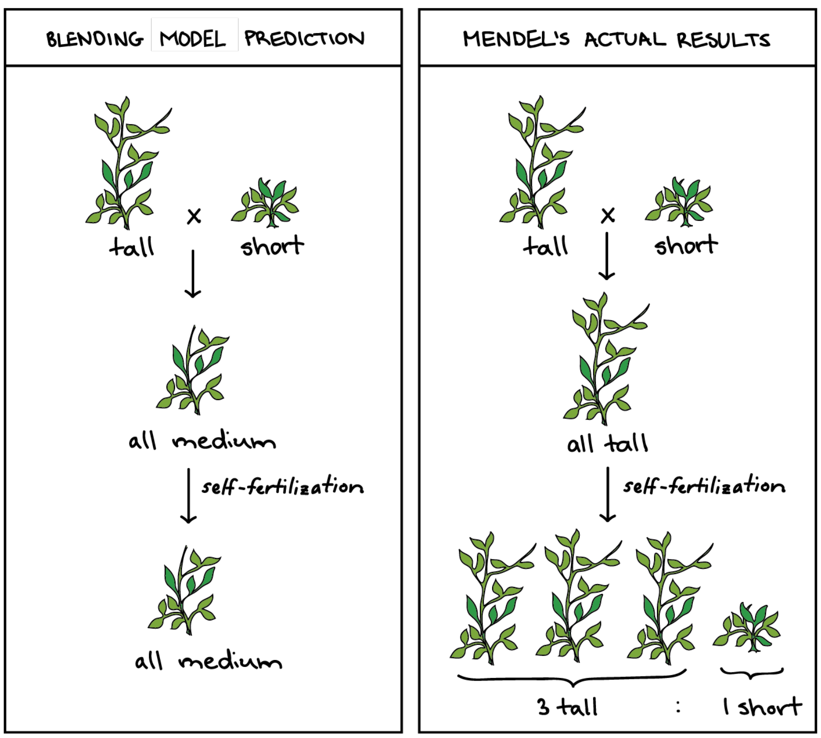
2. In the <u>F_2 generation</u>, if the two copies of a character's information obtained **<u>blended</u>** together in an offspring =

Instead, **what did Mendel actually observe in the F_1 AND F_2 generations** after performing his crosses?

1. In the F_1 generation, if the two copies of a character's information obtained from each parents remain **discrete, separate, and independent** in an offspring:

2. In the F_2 generation, if the two copies of a character's information obtained from each parents remain **discrete, separate, and independent** in an offspring:

5. Dismissing the blending hypothesis, Mendel's proposed **particulate hypothesis of inheritance**: discrete particles of information (today referred to as genes) determine the characteristics of organisms and are passed on from parents to offspring across generations, being independently expressed without the information getting blended. For example, though a plant may inherit information for one trait (tall) for the character height from one parent and information for another trait (short) for the character height from the other parent, the tall and the short information inherited by the offspring are **NOT** blended together in the offspring (F1), turning into medium information (the F1 plant losing the ability to pass down short or tall information from that point on). According to Mendel, the offspring is actually able to still pass down either the tall or the short information to its own future offspring (F2) since this information has not been lost in the F1 parent.



Mendel's act of crossing of true breeding purple and white flowers, followed by him allowing the F_1 generation offspring to self-pollinate in order to produce the F_2 generation, **Figure 14.3**, allowed him to **refute** the blending hypothesis of inheritance!

Mendel studied 7 characters in pea plants, each character existing in plea plants as one of two possible traits. **Review these in Table 14.1.** Mendel called the "information" for each trait that was passed down an "inheritable factor." He did not know of DNA and its ability to encode information in its **genes**. Today, though**, we can think of Mendel's "heritable factors" as genes.** Turns out, without realizing it, Mendel was tracing 7 genes for 7 different characters as they got passed down from one generation to the next.

Remember the **locus** (loci – plural) refers to the physical location of the gene on the chromosome.

a. Taking into account our understanding of modern genetics today, that characters are determined by genes, what is the **reason for the variation witnessed in an inherited characteristic**? *(For example, why can the character flower color exist as the purple vs the white trait based on how genes work)*

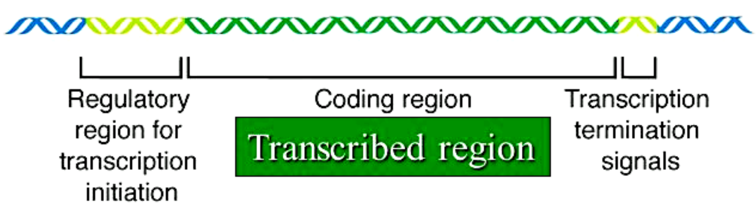
b. In a diploid organism, like the pea plant, **how many copies of a particular gene do its cells contain**?

c. Why does a diploid organism have the number of copies of each gene that you claimed in question 5.b? *(Hint: Think of the chromosomal make up of a sexually reproducing organism)*

Though we will discuss gene regulation in a later chapter, here's an introduction to some aspects of gene structure that you will get to know well. **Study the information below.**

A gene consist of a sequence of DNA nucleotides. *(In the image below, the light and dark green DNA makes up a gene)*

1. One region of the gene contains the section of DNA known as the **coding region of the gene**. The coding region of a gene is the sequence of DNA nucleotides that is copied into certain **non-messenger RNA molecules** (tRNA, rRNA, snRNA, miRNA, etc.) that function as is **OR** that is copied into **mRNA**, which carries instructions to ribosomes so they can make certain polypeptides (the primary structure of a protein - *the protein's covalently-bonded amino acid sequence)*. Recall that one or more folded polypeptides together form a **proteins**.
2. **A gene also consists of controlling elements (regulatory regions)**. The controlling sequences are the regions of DNA nucleotides in the gene that help the gene get expressed or remain silenced. In other words, proteins known as transcription factors can interact with the controlling regions of a gene, effectively "turning on" a gene or keep it "turned off." If a gene is on, RNAs are being made by copying the coding region of the gene (with the help of enzymes known as RNA polymerases). If the gene codes for a protein and the gene is off, no mRNA and, thus, no polypeptide (and so no protein) is being made from the information in the coding region of this protein gene.



Mutations in the DNA can alter the controlling (regulatory) or the coding regions of a gene.

- **DNA mutations** ***(changes in the nucleotide sequence of DNA)*** **in the regulatory elements of a gene, can alter the ability of the gene to be expressed (turned on) or silenced (turned off) properly.** As a result, a cell may not be able to make or stop making a particular RNA or protein.
- **DNA mutations in the coding region of the gene, however, can alter the products formed when expressing a gene.** Mutations alter the nucleotide sequence in the RNA's made from copying the DNA gene's coding region when the gene is expressed (turned on), including mRNA, and, therefore, may also alter the amino acid sequence of the polypeptide made, this change potentially **altering the the folding (structure) and/or function of the resulting protein.**

6. a. **Study Figure 14.4.** The different versions of a gene are called **alleles**. How does one allele of a gene differ from another allele for that same gene as far as the DNA is concerned?

b. In the case of Mendel's pea plant flower colors, why does one allele result in purple flower color formation while the other allele does not? *Your answer should refer to the* ***consequences of expressing the two alleles of the gene***.

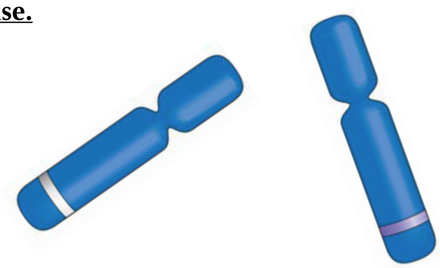
7. a. *Think:* **How many alleles of a gene are found on an individual chromosome**?

   b. *Think:* Though a population of organisms may contain a large number of alleles for a gene, what is the **maximum number of alleles of a particular gene that can be found in the DNA of an individual human being**? Why?

8. **How do we determine which allele of a gene is the "dominant allele" and which allele of that same gene is the "recessive allele**?" *(Hint: We would not determine this by looking at true breeders for a particular character)*.

9. a. Mendel determined a fundamental principle of inheritance that he called the **Law of Segregation**. Explain this principle. *(Today we observe this during meiosis!)*

   b. Below is a pair of homologous chromosomes, one carrying the purple (P) allele and one the white (p) allele for flower color. Add the P and p designations to the figure below in order to label each allele found in the **nucleus of this cell which is in G1 of Interphase.**



   c. Draw what these chromosomes would look like when this cell is in **metaphase 1 of meiosis**. (Refer to Ch.13 if necessary). Make sure you **label the alleles on each molecule of DNA**. *Remember, if a cell in in the M phase of the cell cycle, they have passed through S phase of interphase!*

d. Draw what the **two daughter cells of meiosis 1 would look like** when the daughter cells are both in **metaphase 2**.

Daughter Cell #1: **Daughter Cell #2:**

e. Draw what the **nuclei of the four possible gametes** look like once meiosis 2 is completed and the sister chromatids have been separated in each of the two daughter cells that formed after meiosis 1. (Refer to Ch.13 if necessary)

Nucleus of Gamete #1 **Nucleus of Gamete #2** **Nucleus of Gamete #3** **Nucleus of Gamete #4**

10. Study Figure 14.5 well first. Make sure you understand why the plants in each generation are able to make the gametes (reproductive sperm or egg cells) shown in the figure. What is a **Punnett Square** exactly?

Remember, **a Punnet Square shows you the POSSIBLE ZYGOTES that can be produced, and the PROBABILITY of each zygote being produced, EACH time two organisms mate, given the gametes that the two mating parents make**.

IMPORTANTLY:

- *The Punnett Square does **NOT** tell you how many total offspring will actually be produced by two parents.*
- *It also does **NOT** tell you which of the possible zygote(s) will be produced **NOR** how many of each possible zygote will be produced if more than one offspring is made as a consequence of successful matings of the parents.*

11. Define the following terms after reading your text and reviewing Figure 14.6.

a. A **homozygote** (which is an organism that is homozygous for a particular gene in question) =

b. A **heterozygote** ((which is an organism that is heterozygous for a particular gene in question) =

c. The **phenotype** of an organism =

d. The **genotype** of an organism =

12. a. Review Figure 14.7. What is a **test cross** and why is it useful?

b. *Practice:* Explain how a **test cross** would be conducted in order to determine if a pea plant exhibiting inflated pods is homozygous or heterozygous if the inflated pod allele ***I*** is dominant to constricted pod allele ***i***.

c. *Practice:* What proportion of offspring should exhibit inflated pods if the pea plant from 12.b is a homozygote versus if this pea plant turns out to be a heterozygote? *You should show and discuss the **two possible Punnett Squares**, one at a time, based on the mating you decide to do to derive your answer.* ***Notice that Punnett Square are predictions.***

Scenario #1 - pea plant is homozygous	**Scenario #2 - pea plant is heterozygous**

13. a. Differentiate between a **monohybrid** and **dihybrid** crosses.

b. Using the characters Mendel studied (Table 14.1), what would be the genotypes of the two parents in a **monohybrid cross** for flower position. *(Remember, Mendel used the same letter for dominant & recessive alleles of the same gene, the letter may just be capitalized or lowercase depending on if the allele is dominant or recessive)*

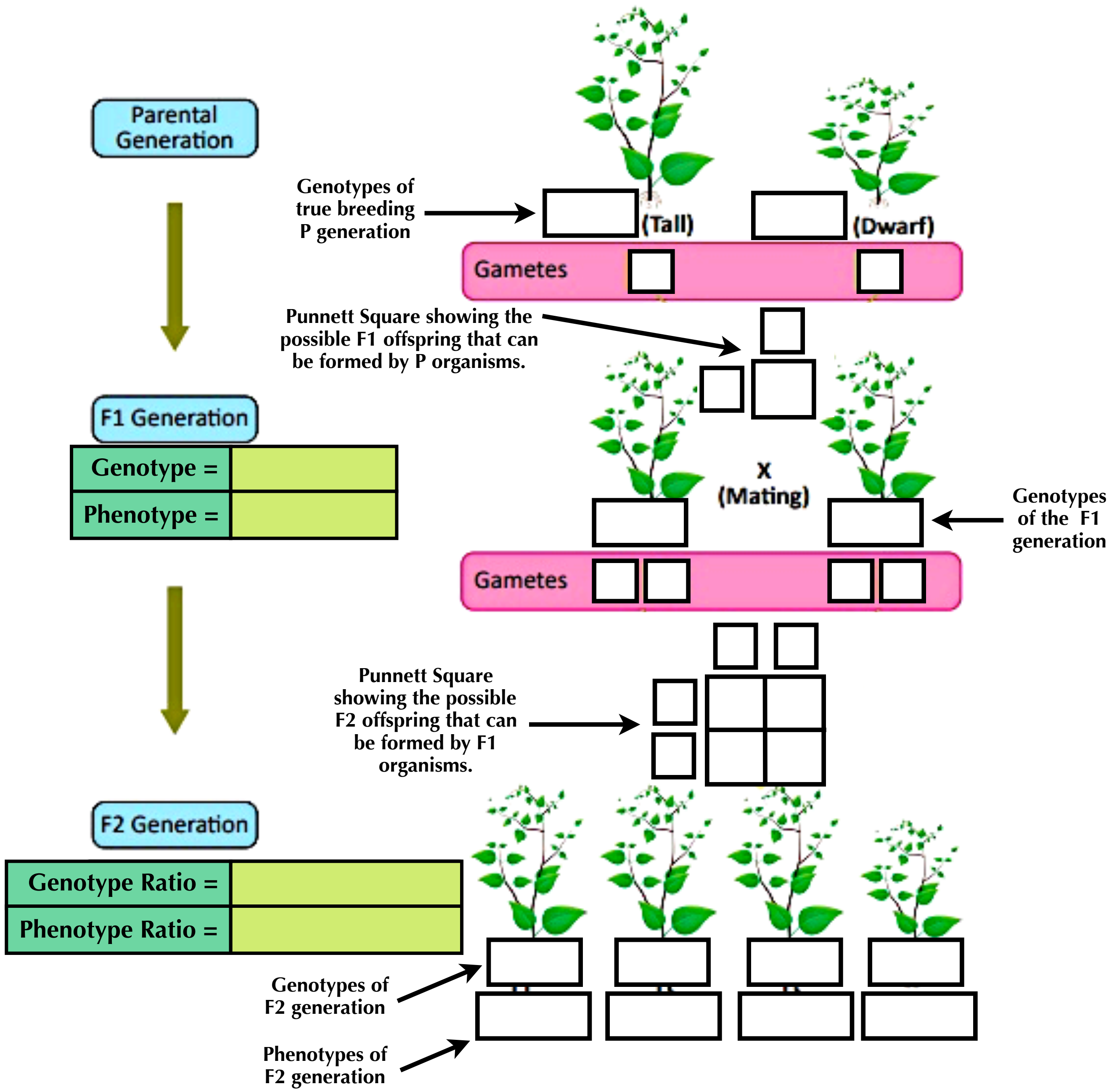
___________ **X** ___________

c. Using the characters Mendel studied (Table 14.1), what would be the genotypes of the two parents in a **dihybrid cross** for pod color and flower color. *(Remember, Mendel used different letter for alleles of different genes)*

___________ **X** ___________

14. All of the characters Mendel studied in pea plants involved two possible alleles, one dominant and one recessive.

a. Using Table 14.1 and Figure 14.5 as your guides, fill in the missing information in the illustration below in which the **P generation is made of two pure breeding parents, one tall and one short.** ***The allele notation to use is T & t.***



b. Which generation is **completely heterozygous**? *(All plants produced are heterozygotes)*

c. Which generation has **both heterozygous and homozygous offspring**? *(Plants produced include heterozygotes and homozygotes)*

15. a. Through his monohybrid crosses that traced the inheritance of **ONE** character **(one gene)**, Mendel designed the **Law of Segregation**. Through his dihybrid crosses that traced the inheritance of **TWO** characters **(two genes)**, Mendel designed the **Law of Independent Assortment**. Explain the **Law of Independent Assortment**.

b. **Unless a genetics problem tells you or hints at you otherwise, assume that any two different genes for two different characters discussed are located on two different types of chromosomes (not on the same homologous pair)! Study Figure 14.8 carefully** and make sure you understand (based on how meiosis works when two different genes are located on two completely different types of chromosomes) how, in Mendel's dihybrid crosses, his F1 generation plants were able to make all four of the possible gametes shown on the top and left sides of the accurate Punnet Square. **Review the stages of Meiosis (Ch.13) before continuing if you are unsure about them!**

16. As you start to work on word problems in genetics, two things are critical: the parents' genotypes must be determined, and you must determine the genotype of their gametes correctly. **Remember gametes are haploid. They should contain one of EVERY type of chromosomes (and therefore one of EVERY type of gene) found in the parent cell's diploid nucleus.**

You should **not** show that diploid parents made diploid gametes with two copies of the same gene (as gametes would be haploid). **So if a parent is Tt, their gametes' genotypes can be T or t, but not Tt.** If you are tracing more than one type of gene in a parent at once, the parent having two copies of each gene because they are diploid (having two sets of chromosomes), your gametes (which have only one set of chromosomes) should also not end up with one of the two genes missing altogether either. **Gametes should have one copy of EACH different gene. So if a parent is TtPP, their gamete can be TP or tP, but not Tt or PP.**

a. Using Figure 14.8 as your guide, what possible gametes can the following pea plant form that is heterozygous for both the height (gene **H**) and flower color (gene **P**)? *(You should show four different possible gametes)*.

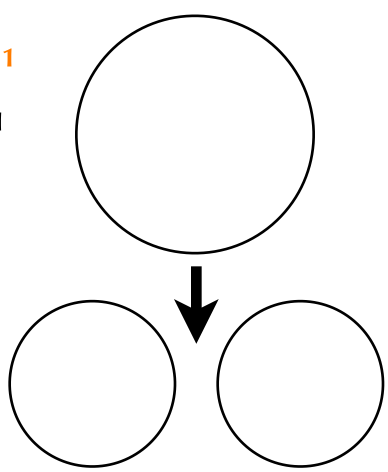
Pea plant's genotype (the parent's genotype) =

Genotypes of all possible gametes this parent plant can produce =

b. The gene for height is located on chromosome 4 in pea plants while the gene for flower color is located on chromosome 1. Knowing what you know about how meiosis occurs, draw the **two ways** the duplicated homologous chromosome pairs (**the chromosome 4 and chromosome 1 tetrads**) could line up at the metaphase plate during metaphase 1, and, thereby, lead to the production of all four types of gametes that you listed above, **showcasing how the "Law of Independent Assortment" relates to what happens in meiosis.** *Make sure your chromosomes drawn are labeled with the correct alleles for each of the two genes on all eight chromatids!!!*

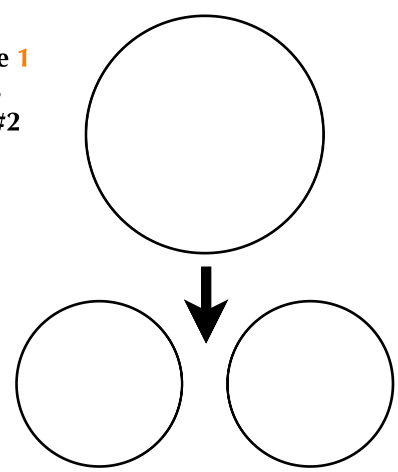
Metaphase 1 of Meiosis Scenario #1

Possible types of different gametes that will form at the end of Meiosis 2 in Scenario #1



Metaphase 1 of Meiosis Scenario #2

Possible types of different gametes that will form at the end of Meiosis 2 in Scenario #2



c. Using the grid below, complete a **dihybrid cross** for two plants that are mated, both plants being **heterozygous for both the heigh and flower color**. Be sure to always **1.** FIRST WRITE THE GENOTYPES OF EACH PARENT INVOLVED IN THE MATING and **2.** to show the **gametes** (reproductive cells) along the top and left sides of the Punnett Square that these parents can make. The boxes in your Punnett Square will show the genotypes of all the offspring that these two parents could potentially produce after their gametes undergo **fertilization**.

Parent #1 Genotype ____________________ **X** ____________________ **Parent #2 Genotype**

d. Provide the **genotypic ratio of the offspring** of your dihybrid cross. *(To help you out, an example of the genotypic ratio of the offspring resulting from the monohybrid cross for flower color Pp x Pp is **1 PP : 2 Pp : 1 pp**)*

e. Provide the **phenotypic ratio of the offspring** of your dihybrid cross. *(To help you out, an example of the phenotypic ratio of the offspring resulting from the monohybrid cross for flower color Pp x Pp is **3 purple : 1 white**)*

f. **A Punnett Square shows you which possible offspring could be produced EACH time the two parents in question mate. It also tells you the PROBABILITY of getting each type of possible offspring.** Let's say the cross between the two parents in 16.c results in 160 offspring. How many of those offspring are **expected** to be tall and have white flowers? *Show your calculation **AND** explain it in words.*

17. a. Pea plants heterozygous for flower position and stem length (AaTt) are allowed to self-pollinate (see Table 14.1 to know which allele is dominant). 400 of the resulting seeds are planted. Draw a **Punnett Square** for the cross. *Make sure your **gametes are haploid** and contain a copy of **EACH** gene as gametes contain one full set of DNA, made up of one copy of each type of chromosome. (Check your answer by going to the **Ch.14.1 Concept Check Question #1** answer in Appendix A)*

b. How many offspring would be predicted to have terminal flower and be dwarf? *Check your answer by going to the **Ch.14.1 Concept Check Question #1** answer in Appendix A) - Explain in words and show your math calculations.*

18. a. List the different **gametes** (not the offspring genotypes) that could be made by a pea plant heterozygous for seed color, seed shape, and pod shape (PARENT GENOTYPE: **YyRrIi**). Remember again, gametes are haploid so they have **one** set of every chromosome. Therefore, assuming these three genes are on three different types of chromosomes for now, each gamete will have **one** copy of **EACH** gene too. *Check your answer by going to the **Ch. 14.1 Concept Check Question #2** answer in Appendix A)*

b. How large a Punnett Square (how many boxes) would you need to be able to predict the offspring of a self-pollination of this trihybrid? **EXPLAIN by stating how many gametes you would need to show along the side and along the top of the Punnett Square.** *(Tip: When self-pollination occurs, the "two parents" are really the same organism, but different cells in this parent organism undergo meiosis to make the male vs female gametes. Check your answer by going to the **Ch.14.1 Concept Check Question #2** answer in Appendix A)*