

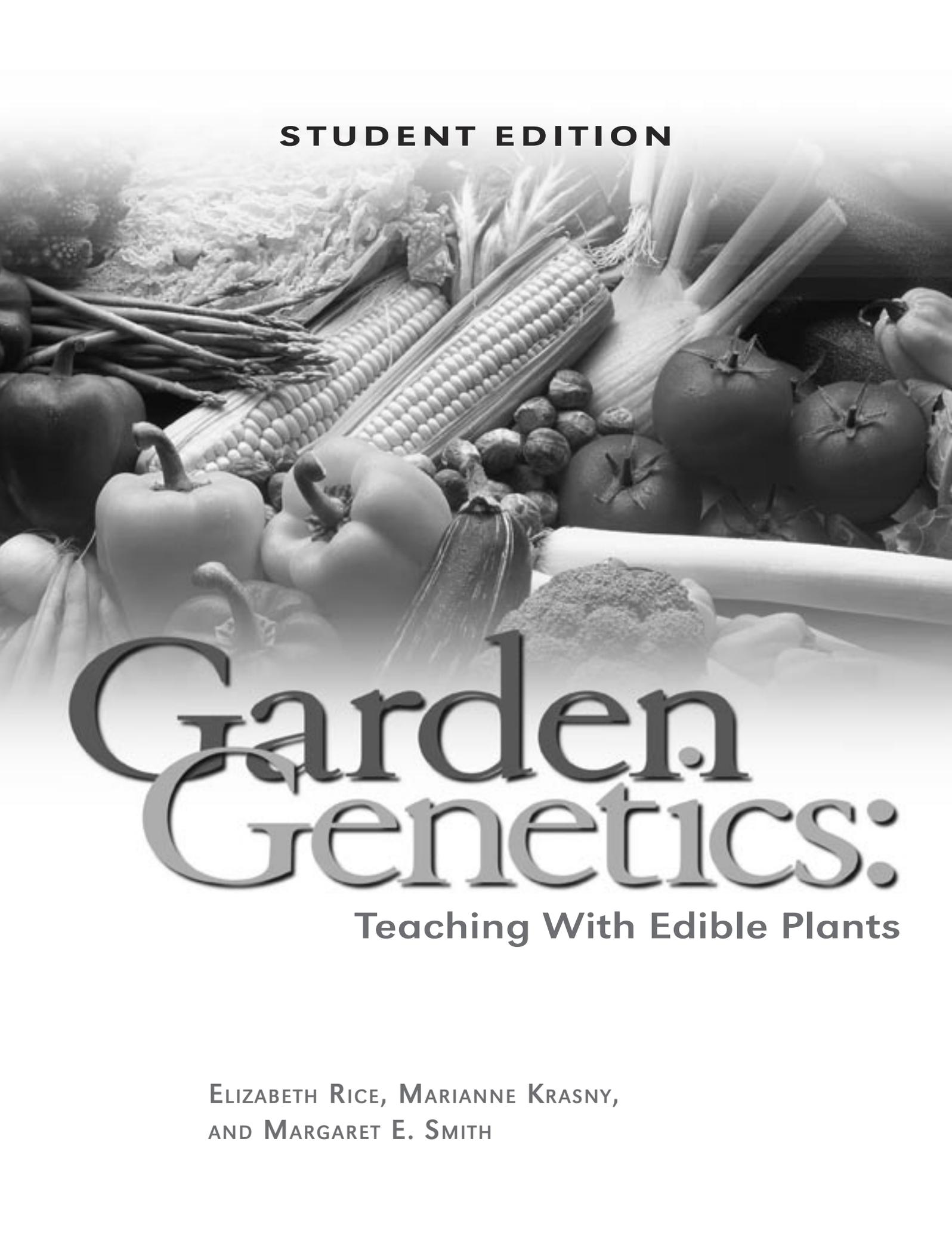
**STUDENT EDITION**



# Garden Genetics:

Teaching With Edible Plants





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# Garden Genetics:

Teaching With Edible Plants

ELIZABETH RICE, MARIANNE KRASNY,  
AND MARGARET E. SMITH



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# STUDENT EDITION

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# INTRODUCTION TO GARDEN GENETICS

## *Student Edition*

How do farmers grow the sweetest ears of corn possible? How do they grow huge red tomatoes? How do they make sure none of the cucumbers they grow are bitter? It's all genetics, and it's big business. A patent on a gene can be worth millions of dollars! *Garden Genetics* uses a series of inquiry activities and experiments to explore both traditional and cutting-edge genetics. Throughout the text and activities, you will investigate the connections between genetics, evolution, ecology, and plant biology.

With *Garden Genetics* you'll study science in the context of familiar foods. The readings and activities focus on cucumbers, corn, and tomatoes. They also address issues you hear about in the news—like the environmental and social impacts of genetically engineered food plants.

The activities in this book present genetic concepts in ways that are new and exciting. To learn about Punnett's squares, you will taste variation in bitterness of cucumber seedlings and trace these differences back to the parental generations. You'll then go on to design and conduct experiments investigating the surprising role that bitterness plays in protecting cucumber plants from insect predators. To learn about the genetics of plant breeding, you will re-enact a trial in which farmers sued seed companies to compensate for one billion dollars of U.S. corn crop losses caused by genetic uniformity! Other activities include creating geographic maps of the origin of food plants (Where did tomatoes originate? If you guessed Italy, you're wrong!); and genetic maps of economically important traits like tomato color (the redder the better, and genes control it).

The activities in this book present a unique way of looking at food and agriculture—one that applies textbook concepts in an exciting, innovative, and interesting context. We hope you will enjoy this exploration of genetics, evolution, ecology, and plant biology—along with tasty vegetables and healthy learning!



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In a SciLinked text, such as this one, you'll find a logo and keyword near a concept, a URL ([www.scilinks.org](http://www.scilinks.org)), and a keyword code. Simply go to the SciLinks website, type in the code, and receive an annotated listing of as many as 15 web pages—all of which have gone through an extensive review process conducted by a team of science educators. SciLinks is your best source of pertinent, trustworthy internet links on subjects from astronomy to zoology.

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# “IT SKIPS A GENERATION”

## *Traits, Genes, and Crosses*

Long before they understood why the strategy worked, farmers knew how to crossbreed plants to obtain more desirable traits. Even today, a farmer who knows nothing about genetics can tell you that when a blue type of corn crosses with a yellow one, the offspring are blue. However, the farmer might add, if you cross a corn plant with small ears with a large-eared one, the offspring will have ears that are intermediate in size. Without any knowledge of genetics, the farmer has just told you a great deal about how the genes for blue color and for ear size work.

Gregor Mendel, an Austrian monk often described as the “father of genetics,” worked with pea plants in the 1860s to understand how traits are passed from one generation to the next. Mendel made his discoveries by making crosses between **true-breeding** pea plant populations with different characteristics and keeping careful track of the characteristics of their offspring. Sometimes, when he transferred pollen from one tall plant to another tall plant (like in the cross shown in the F1 generation of Figure 1.1), some of the offspring were tall but some also were short. Where was this shortness coming from, if not from the parental populations?

“It skips a generation”—the shortness was coming from the grandparental populations. Shortness, the **recessive trait**, was masked by the tall **dominant trait** in the “**hybrid**” or F1 generation. In essence, the shortness was hidden because of sexual recombination. Each offspring receives one copy of a gene from its mother and one from its father. In this way, gene combinations are shuffled with every generation and new types may appear.

Many of the early discoveries in genetics occurred in plants. Plants have a few special characteristics that make them ideal for studying genetics. From one known cross, many genetically similar “siblings” are produced. Pea pods, like the ones Mendel worked with, produce about five peas, and a cucumber has hundreds of seeds. Furthermore,

A tall plant population that has all tall offspring (when crossed with itself or another tall population) is **true-breeding**.

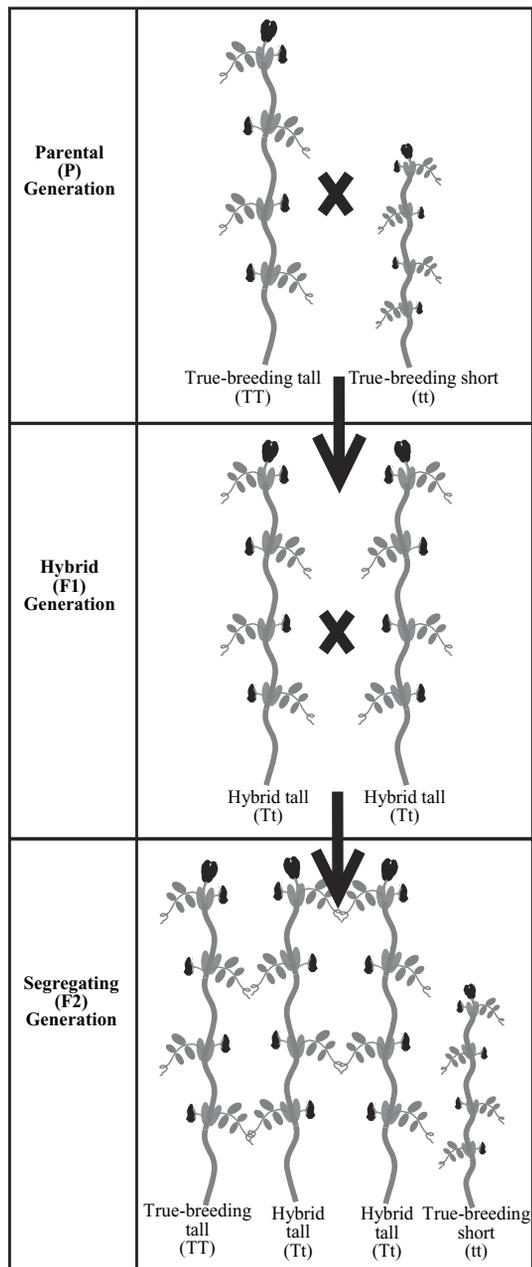
A **recessive trait** is not expressed unless two copies of a gene are present. A single copy of a recessive gene is “hidden” by the presence of a **dominant trait**.



Topic: Gregor Mendel  
Go to: [www.sciLINKS.org](http://www.sciLINKS.org)  
Code: GG01

Topic: Dominant and Recessive Traits  
Code: GG02

**Figure 1.1. Crossing generations. When plant breeders make crosses between plants, they talk about the parental (P), hybrid (F1), and segregating (F2) generations.**



some plants (but not all) have the remarkable capability of being able to fertilize their own flowers. This means that the same plant can be both the male and female parent of a seed. Therefore, scientists can easily and naturally create whole populations of genetically identical individuals.

The cross in Figure 1.1 resulted from two true-breeding individuals. The F1 generation would have contained 5–10 seeds that were genetically identical to one another for the alleles that determine height (all had the Tt alleles). To make the F2 generation, Mendel had two options: He could self-pollinate the plants, or he could cross two different individuals of the F1 generation. Regardless of which method he used, in the F2 generation, the individuals would not all be genetically identical!

### HYBRID CORN AND SEGREGATION OF TRAITS

Why do seed companies like Dekalb and Pioneer make corn seed, when farmers already have seed they can plant?

The key lies in a concept called hybrid vigor. It's a phenomenon that scientists still don't fully understand, and accounts for most of the increased harvest from farmers' fields since the 1920s. The process works like this: A corn breeder takes two very different, true-breeding types of corn as parents. When the corn breeder makes a cross between the right two corn types, the F1 generation, called the **hybrid** generation, can have a 30% gain in yield compared to the parents. To a farmer, this translates into 30% more money in his or her pocket.

So why would a farmer ever have to buy expensive, new seed again? The corn plant makes seed for the next generation. However, what happens in the F2 generation? Traits begin to segregate, meaning that at all the plant's genes, AA, aa, and Aa genotypes are possible, instead of the uniform Aa in the hybrid generation. As segregation happens, the yield advantage disappears. This can mean 30% less money in the farmer's pocket—a powerful incentive to keep buying hybrid seed.

From the company's perspective, if people are willing to keep buying seed, the company will keep producing new varieties. Thus, the segregation of traits contains the key to an entire seed industry!

## Mendelian and quantitative traits

Bitterness in cucumbers is a Mendelian trait, meaning that it is controlled by a single gene—just like the traits that Mendel studied in peas (round versus wrinkled, or yellow versus green). Mendelian traits are also sometimes called **single-gene traits**, or traits under simple genetic control. With a single-gene trait, inheritance and behavior are fairly easy to understand.

Many traits, like yield, flowering time, plant height, and color, are more complex and are controlled by multiple genes. These complex traits are called **quantitative traits**. Table 1.1 has examples of both Mendelian and quantitative traits. Note that some traits like plant height can be both Mendelian and quantitative. For example, plant height in normal plants is influenced by many genes. However, in plants with dwarfing genes, plant height behaves as a Mendelian trait. In essence, a single dwarfing gene overrules the otherwise quantitative trait of plant height. Table 1.1 also shows the abbreviations that scientists often give single gene mutations, like “dw1” for a dwarfing gene or “y” for a yellow gene.

**A Mendelian or single-gene trait is controlled by a single gene.**

**Quantitative traits are controlled by many genes.**



**Topic:** Mendel's Laws  
**Go to:** [www.sciLINKS.org](http://www.sciLINKS.org)  
**Code:** GG03

**Topic:** Explore Mendelian Genetics  
**Code:** GG04

**Table 1.1. Mendelian and quantitative traits.**

	<b>Mendelian</b> (single-gene)	<b>Quantitative</b> (multi-gene)
<b>Cucumber</b>	Spiny—controls the production of small spines on the fruit, producing a prickly cucumber.	
	Bushy—controls whether the plant grows as a bush or as a vine.	
<b>Tomato</b>		Fruit size—About 12 genes control fruit size by impacting characteristics like cell division in the fruit and growth hormones.
<b>Corn</b>	Dwarf (dw1)—controls the production of gibberellin, a plant hormone responsible for vertical growth.	Plant height—More than 20 genes are important in plant height in corn.
	Yellow (y)—controls whether a kernel is yellow or white.	Kernel color—Many genes modify exactly what shade of yellow a corn kernel will be, from canary yellow to a pale cream.
		Yield—The most important trait of all is influenced by dozens of genes that affect things like number of rows on an ear, number of kernels, kernel size, kernel density, and plant tolerance of competition in a field.

**Questions for further thought**

Evolution: What evolutionary advantage might reshuffling genes, caused by sexual reproduction, give to a new generation of plants?

What disadvantages could it have?

Genetics: When a blue type of corn crosses with a yellow type of corn, the offspring are blue. What type of trait is involved?

When a corn plant with large ears crosses with a small-eared plant, the offspring will have intermediately sized ears. What type of trait is involved?

If a true-breeding spiny cucumber plant crossed with a non-spiny cucumber always had spiny offspring, how many copies of the spiny allele would it have?

How do geneticists and plant breeders know if a plant is true-breeding?

## **Activity 1.**

### ***Edible Punnett's Squares—Segregation Ratios You Can Taste***

#### **Objective**

To discover whether the bitter gene in cucumber plants is dominant or recessive.

#### **Background**

Cucumber plants, as well as their close relatives the squashes and melons, make a unique protein called cucurbitacin. Cucurbitacin tastes bitter to humans. Bitterness in cucumbers is caused by a single gene that has a recessive and a dominant allele. Your task in this assignment is to use your knowledge of genetics, particularly your understanding of crosses and Punnett's squares, to figure out how this bitter trait behaves. (Is bitterness dominant or recessive?) This is how scientists traditionally have learned about genes. They use populations of cucumbers or other organisms, make crosses, and use statistics to test their hypotheses about how genes behave.

#### **Materials**

- A population of “unknown” plants at cotyledon stage—about 10 days old
- Populations of bitter and non-bitter plants to act as taste controls—about 10 days old
- Plant tags
- Pencil
- Calculator (optional), for Part IV statistical analysis

#### **Safety Notes**

- Under normal circumstances, you should never taste anything in a biology laboratory. However, this laboratory makes an exception by asking you to taste a tiny piece of a cucumber plant's leaf.
- Students who are allergic to cucumbers, squash, melon, or zucchini should NOT taste the plants.
- If you are allergic or not comfortable tasting the plants, please ask someone else in your group to do it for you.
- You should wash your hands after handling the plants.
- You should wash your hands AGAIN at the end of the activity.

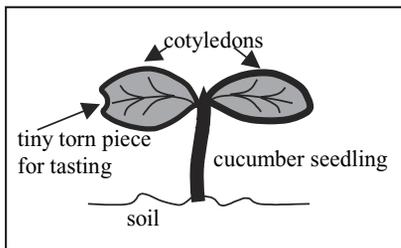


**Topic: Punnett Squares**  
**Go to: [www.sciLINKS.org](http://www.sciLINKS.org)**  
**Code: GG05**

## Activity

### Part I. Your unknown population

**Figure 1.2. Tasting the cotyledons of a cucumber seedling.**



1. Taste\* the controls your teacher has set out. Tear a tiny piece off the edge of one of the cotyledons (see Figure 1.2). Chew the leaf between your front teeth, biting into it many times, and letting the flavor wash over your tongue. Can you tell the difference between bitter and non-bitter? Do you and your partner agree?

\*Students who are allergic to cucumbers, squash, zucchini, or melon should not taste the plants.

2. Taste your own plants. Are they bitter? Non-bitter?
3. Once you have decided whether each of your plants is bitter or non-bitter, label that plant with a tag and place the tag in the soil next to the plant.
4. Taste your partner's plants. Are they bitter? Non-bitter?
  - 4a. Do your answers agree? Why or why not?
  - 4b. What can you do to improve your measurement?

*Traits, Genes, and Crosses*

5. Collect the totals for the class. (Sample below)

<b>Sample calculation</b>	<b>Bitter</b>	<b>Non-bitter</b>	<b>Total</b>
Number of plants			
Percentage			
Ratio			

To find the percentage, divide the number of plants in the bitter and non-bitter categories by the total number of plants. To find the ratio, divide the larger of the bitter or non-bitter number of plants by the smaller number of plants. Your results will probably not be perfect, whole numbers.

6. To figure out the genotypes of the parental generations, you need to know which genotypes go with which phenotype.

6a. What is a phenotype? What are the phenotypes of your plants?

6b. What is a genotype?

7. Which phenotype is there more of?

At this point we don't know which allele is dominant. But you can make a hypothesis (an educated guess) using your data. In Part IV you will test whether or not the data support this hypothesis. Right now, there isn't a "right" answer, but there are two logical ones.

## CHAPTER 1. "IT SKIPS A GENERATION"

8. Make a hypothesis about which trait (bitter or non-bitter) is dominant. This will be the hypothesis you test in this activity. Support your hypothesis.

9. Using your hypothesis from the last step, what symbol do you choose to represent the bitter allele? (Remember that dominant alleles are usually given a capital letter. Recessive alleles are usually given the same letter, but lowercase.)

10. What symbol do you choose to represent the non-bitter allele?

11. To summarize, fill in the table according to your hypothesis from step 8.

	<b>Bitter</b>	<b>Non-bitter</b>
<b>Number</b>		
<b>Possible Genotypes</b>		