Food Up!
URBAN AG CURRICULUM

Module 3: How to Feed a Plant: What our Food Needs to Grow

Goals and Objectives:

What is required to grow healthy food? How does one “feed a plant”? What type of environment—soil, temperature, precipitation—is optimal for crops? Why does this matter?

In this lesson, students will explore the necessary elements for plant growth and consider how each relates to photosynthesis, energy storage, and energy transfer in crops. Students will gain a basic understanding of how environmental factors, such as climate zones, influence plants and crops across the globe. Using a hands-on hydroponic activity, students will have an opportunity to think specifically about the importance of water. In Activity #3, soil type and texture will also be addressed, helping students make connections between soil health, agriculture, and human health.

Students will also be introduced to the concept of *companion planting*, demonstrated via a tour of a *Three Sisters* Garden (where squash, beans, and corn are planted together). The lesson ends with a card game that will help students further consider how plants work synergistically to support one another through companion planting.

Time: 1 hour 10 minutes

Optional additional activities: 35 minutes

Materials:

- ☐ Module 3 Teacher Print Kit
- ☐ Module 3 Student Handouts
- ☐ Whiteboard OR large paper and markers
- ☐ Tape and string
- ☐ Empty 2-liter soda bottles with caps (1 per student Activity #1, 4 for Activity #3)
- ☐ Cotton material (an old T-shirt works well)
- ☐ Thick nail and hammer OR utility knife (something to poke a hole in a bottle cap with)
- ☐ Scissors (1 pair for every 3 students)
- ☐ A small plant or seedling for each student (herbs, like basil, work well here)
- ☐ 4 coffee filters
- ☐ Potting Soil and scoop for the soil
- ☐ Large mixing bowl
- ☐ Access to water
- ☐ Liquid measuring cup
- ☐ Dry 1 cup measuring cup
- ☐ 1.5 C Sand
- ☐ 1.5 Clay (in dry, powdery form, such as from a potter’s shop or craft store)
- ☐ 1.5 C Silt
- ☐ Permanent marker
- ☐ 8 jars or cups (large enough to fit a measured cup)

Optional:

- ☐ Mature Three Sisters Garden for observation
- ☐ Four magnets for posting cards on the whiteboard

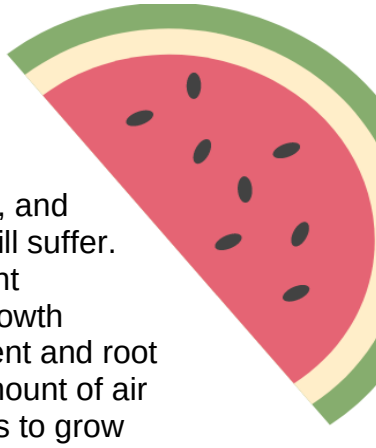
Teacher Background:

Soil, nutrients, water, air, and sunlight are all necessary for plant growth and energy creation via photosynthesis. Nutrients are provided through organic matter in the soil and are absorbed through plant roots as a solute in water. Photosynthesis, the plant process that converts carbon dioxide in the air into storable energy in the form of glucose, requires both sunlight and chlorophyll. Nutrients and water are used to move the glucose and to store it for use in plant growth and setting fruit. It is important for students to grasp the basic components of photosynthesis as they consider what factors impact food production.

Temperature, precipitation rates, and soil characteristics vary dramatically across the globe. Variations in both climate and local ecosystems impact the types of crops that thrive across regions. In this lesson, we will explore five major world climates: polar, temperate, Mediterranean, arid, and tropical. We will use ideal growing condition information for a variety of crops to help students match the crop to the appropriate climate. This will help students explore how nutrients, water, air, and sunlight conditions vary, and how these changes are reflected by farming different foods. As they consider the broader food system, understanding regional and climatic differences will help students come to terms with both limitations and opportunities in agriculture.

Another key aspect of this lesson is helping students understand soil as the foundation of any garden or agriculture system. With your help, they will recognize that soil both provides nutrients and facilitates water availability to crops. A useful way to think about soil is in the context of agricultural practices. Careful management of nutrients and organic matter can enhance *soil fertility*, which is the ability of soil to supply nutrients for plant growth.[1] Over-taxing soils through continuous planting of the same crops, removing organic matter, over-fertilizing, compacting, or frequent soil tillage can deplete soil fertility. Building up soil organic matter (SOM), derived from all the plant or animal materials found in soil at various stages of decay, is one key way to enhance fertility by providing nutrients to plants in forms that are available for uptake. It also creates a favorable environment for soil organisms to live. Overall, SOM plays a sizeable role in the physical, chemical, and biological properties of soil, including soil structure, moisture-holding capacity, biodiversity, and nutrient availability.[2]

The often-overlooked physical structure of soil certainly impacts soil quality and is a concept your students should become familiar with. Soil structure—the arrangement of individual soil particles with one another—manifests in infinite arrangements across soil types and is determined by the level of aggregation.[3] SOM is crucial for the development and maintenance of optimal soil structure for plant growth.



Soil structure governs soil porosity, air and water content, permeability, tilth, and aggregate stability. When SOM declines, soil productivity and crop yields will suffer. Thus, ensuring there is plenty of organic matter in the garden is an important consideration for all farmers. Granular soil structure is desirable for plant growth because it provides both small and large pores that facilitate water movement and root growth. Pore space, formed by the position of aggregates, regulates the amount of air and water in the soil, the permeability of soil to water, and the ability of roots to grow easily.[3]

This basic background information on soil should help you discuss its importance with your students. Please see the Garden Strategies cards (in the Bonus Card Deck) on **Soil Organic Matter**, **Compost**, and **Mulching** for more information on how to apply these principles to your garden.

In the last section of this lesson, students will learn about companion planting, or grouping plants in the garden that work well together. We will consider how plants help one another by providing shade or trellising, fixing nitrogen, regulating water evaporation, and/or luring or repelling pests. These synergistic relationships are a natural way to improve crop growth and promote soil fertility.

We will explore the example of the Three Sisters Garden, an ancient Native American growing strategy that pairs the nitrogen-fixing power of pole beans, the trellising power of corn, and the shade, weed, and pest protection of squash. Many tribes interplanted this trio because the crops thrived together, much like inseparable sisters.

Opening Discussion:

Start this lesson with a group discussion on the basics of plant growth. Aim to link the principles discussed to food production whenever possible.

First, encourage students to brainstorm: *What do plants need to thrive?*

Write ideas on the board.

Examples: Soil, Water, Sunlight, Heat, Nutrients, Air, Carbon Dioxide

- *Why do some crops grow in certain places, but not others?*
- *Do we ever try to force crops to grow in places they are not well-suited for?*
- *How does what grows in our local area impact our diets? Has this changed throughout history?*
    - You might use this opportunity to reflect on how processing and increased transportation has widened our diet choices outside of our immediate climate area. Until modern times, diets were limited to what could be grown in the climate around us.

Activity #1: Crops Around the World

Time: 15 minutes

Materials:

- ☐ Whiteboard OR large paper and markers
- ☐ Teacher Print Kit
  - ☐ Includes: Module 3 Teacher Cards: Soil and Nutrients, Water, Sunlight, Air (pages 2-3)
  - ☐ Includes: Plant Climate Map Answer Key (page 1)
- ☐ Student Handouts
  - ☐ Includes:
    - Plant Elements (page 2)
    - Climate Map (page 4)
    - Climate Key (page 5)
    - Climate Plant Cards (pages 6-7)
- ☐ 18 magnets (if using whiteboard) or tape
- ☐ Tape
- ☐ String
- ☐ Scissors

Prep:

- ☐ Cut 9 strings into approximately 2-foot-long pieces
- ☐ Cut out 9 Climate Plant Cards and the 4 Plant Elements

Lesson:

1. Post pictures of soil and nutrients, water, sunlight, and air on the board or paper using tape or magnets. Ask students why each of these elements are needed and write the reasons in a list under each picture. Use the Teacher Cards (Teacher Print Kit pages 3-4) to help facilitate discussion.

2. Ask students, *how could each of these elements be different in different regions of the world?*
   a. Examples:
      - Soil can be sand, loam, or clay.
      - Rainfall rate or annual volume can be different.
      - Sunlight duration and intensity varies in different parts of the globe.

- The world has areas of vastly different temperature patterns.

3. Post the Climate Map and Climate Key on the board. (Student Handouts pages 4-5). Pass out tape and string to each student.

    a. Read aloud the definitions of each climate zone and go over the key on the chart.

    b. Ask for a student volunteer to hand out all the Plant Cards (Students Handouts pages 6-7), reading the growing information on the back of the card aloud as they hand out the cards. (Students can share a card if there are more than 9 students or have more than one card if the group is less than 9 students.)

    c. Ask students to come up one by one and stick their card to the board around the outside of the climate map. Then, ask students to use their strings, along with magnets and tape, to link the card to an area of the world they think would provide the ideal growing conditions for their plant. If you'd like, the group can discuss whether they agree with each post as it happens and why.

    d. Use the climate map answer key together to assess whether the group got the growing regions correct!

End this Activity by helping students make a personal connection to food. Discuss:

- *What climate zone is your family from? What crops grow in this region? Do your family food traditions mirror the foods that are grown in your family's area or origin?*
- *Pick a country and think of a meal that you associate with that country. Do the foods match the region not only in culinary terms, but in botanical terms as well?*
- *It is possible to buy or find crops in regions where they do not typically grow. Why is this the case? What are the pros and cons of moving food around in this way?*

Activity #2: Hydroponic Growing Column

Time: 40 minutes

Materials:

- ☐ Empty 2-liter soda bottle with bottle cap (1 per student)
- ☐ Cotton material (an old T-shirt works well)
- ☐ Potting Soil
- ☐ Scop for the soil
- ☐ Large mixing bowl
- ☐ Access to water
- ☐ Thick nail and hammer (something to poke a hole in a bottle cap with)
- ☐ Scissors (at least 1 per every 3 students)
- ☐ A small plant or seedling for each student (herbs, like basil work well here)
- ☐ Student Handouts
    - ☐ Includes: Hydroponic Growing (page 8) (you may want to print 1 per group of 3 students for ease of reference)

Prep

1. Poke or drill about a 1 cm hole in the bottle caps with a nail, awl, or drill. Alternatively, make an X in each cap with a utility knife.

2. Mark a line on each bottle where the plastic should be cut with a permanent marker. Bottles should be cut about an inch below where the top stops tapering.

3. Cut or tear cotton material into approximately 1” wide, 5” long strips.

4. Fill the bowl with water.

Lesson:

1. Post the sunlight, water, air, and soil and nutrients pictures from Activity #1 on the board again. Explain that we will be making a ‘mini climate’ with everything necessary for a plant to grow.

2. Pass one of the below out to each student:
    - Bottle with cap
    - Cotton strip
    - Scissors (can be shared with other students)

3. Ask students to:
    - Remove the label from their bottle.
    - Cut around the circumference of the bottle at the mark (see Image A)
    - Saturate the cotton strip by dipping it in the water bowl.
    - Thread the cotton strip (wick) through the cap (about halfway).
    - Fill the bottom of the bottle with about 2” of water.
    - Flip the top of the bottle over and rest it inside of the bottom part of the bottle.
    - Hold the cotton strip straight up while scooping potting soil into the top of the bottle (this ensures that the water will wick from the bottom of the bottle into the soil at the top).
    - Plant the plant in the soil so that the root is completely covered in soil.
    - Lightly water the plant.

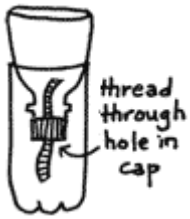


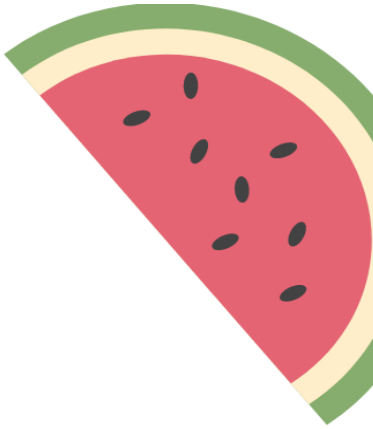
Image A

4. Ask students: *How will you ensure that your plant gets all the elements it needs to grow?* They can look at the pictures posted on the board to brainstorm.

5. When all the students are done planting, ask them to come up with ways they could change the climate for their plant. Ask: *How could we make this plant’s environment:*
    - …*more tropical?*
        - Examples:
            - Increase humidity by putting another bottle top over the plant to keep water evaporation inside
            - Put the plant in a sunny window.
    - …*more arid?*
        - Examples:
            - Use sand as soil so that the soil holds less water.
            - Let the bottom chamber go dry for a time.
    - …*more polar?*
        - Examples
            - Keep the planter outside during the cold season.

Discussion:

- *People often alter the growing environment to produce foods we love in new places or at different times of the year. Think of a few ways that you could have tomatoes longer than the regular growing season in the temperate Midwest.*
    - Start seeds indoors in a window.
    - Place plants in a greenhouse so they won't freeze in the late fall.
- *Plants put their energy generated from photosynthesis into their fruits. Photosynthesis requires a lot of sunlight and water. What is one way you could change a plant's environment to increase fruiting?*
    - Examples:
        - Increase sunlight by reducing structures and large plants around plants that require full sunlight.
        - Add a sprinkler to a garden plot to ensure regular access to water.



Activity #3: Healthy Soil = Healthy Food

Time: 15 minutes

Materials:

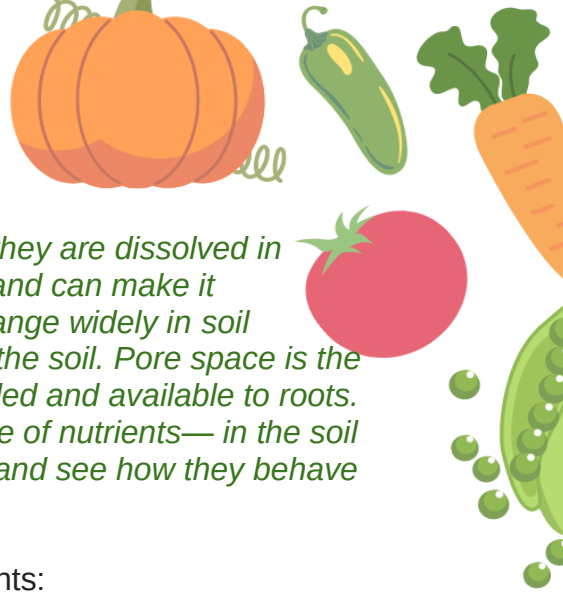
- ☐ 4 empty soda bottles with cap
- ☐ 4 coffee filters
- ☐ Liquid measuring cup
- ☐ Dry 1 cup measuring cup
- ☐ 1.5 C Sand
- ☐ 1.5 C Clay (in dry, powdery form, such as from potter's shop or craft store
- ☐ Scissors
- ☐ Permanent marker
- ☐ 8 jars or cups (large enough to fit a measured cup)
- ☐ Thick nail and hammer OR awl OR utility knife OR drill (something to poke a hole in a bottle cap with)

Prep:

1. Drill or punch 1 cm holes in each bottle cap.
2. Prepare the bottles as if you were making a planter above, but leave out the soil, cotton strip, and plant.
3. Put a coffee filter in the top chamber of each bottle.
4. Label the bottles:
    a. Sand
    b. Silt
    c. Clay
    d. Loam
5. Fill each cup with a measured cup of water.
6. Fill 1 cup with a cup of sand, one with a cup of silt, and another with a cup of clay.
7. Set out each bottle system next to the corresponding cup of soil type on a table.

Lesson:

Soils hold plant nutrients and water, both necessary ingredients in the process of making energy, or photosynthesis. Roots break through the soil and act as vessels to soak up the nutrients and water in the soil and bring them to the plant. Roots can grow deep into the soil and act to anchor the plant in the ground.



The only way that nutrients can be carried through a root is if they are dissolved in water. Different kinds of soils hold different amounts of water and can make it easier or harder for roots to get to that water. Though plants range widely in soil preference, most garden plants like about 50% pore space in the soil. Pore space is the gap in-between soil particles where water and air are suspended and available to roots. These pores allow nutrients from organic matter—a key source of nutrients— in the soil to be released to plants. Let's look at different textures of soil and see how they behave when it rains.

1. Pass around the cups of sand, silt, and clay. Ask students:
    - *Which soil particles are the smallest? The largest*?
        i. Answer: Sand is largest, clay is smallest
    - *Which soil do you think will be hardest for roots to push through?*
        i. Answer: Clay is the hardest because pores are small, and particles are tightly compact.
    - *Which soil do you think will hold water best? Which will drain best?*

Now, let's do an experiment to see if we were right…

2. Once all three soils are returned to the table, ask three students to come to the front and add their soils to the top chamber of the bottle.

3. Next, ask the three students to pour a cup of water over their soil at the same time. Ask all students to notice which soil holds water, and which drains the fastest. After water has drained, pass around the wet samples in the tops of the soda bottles. Give the students an opportunity to observe the consistency of each soil with their eyes and to assess it with their hands. You may want to explain the following:
    - *Clay is great for holding onto water and nutrients; however, the soil particles are so small that they easily clump together when wet. This can make it hard for roots to push into and through the soil. Additionally, there are little pores for air and water. Poor drainage and lack of oxygen to the plants' roots are risks of clay soil.*

    - *Sandy soils are easy for plants to root in. However, the water and nutrients drain quickly from the sand, so many types of plants would die of lack of water. Notice that silt may hold water better than sand, but pure silt lacks pore space for water and oxygen.*

    - *Many soils have a combination of clay, silt, and sand, which together creates proper drainage and pore space. 40% sand, 40% silt, and 20% clay makes a soil type called loam.*

4. As a group, mix a cup of loam using the ratios above (this doesn't need to be exact), and have a student measure out 1 cup of it into the last with a coffee filter and pour a cup of water through it. Pass the sample around to be observed.
    - *How does the loam compare in water retention and drainage to the rest of the soils?*

    - *When you touch the loam, does it seem to hold more or less pore space than the rest of the soil types?*
        i. The combination of particle sizes in loam creates a structure that supports more pore space for water and air.

5. Organic Matter Discussion:
    - *Soil is more than just sand, clay, or silt. Plants also require organic matter to get the nutrients that they need to flourish. Nutrient-rich soil organic matter (SOM) is derived from all the plant or animal materials found in soil at various stages of decay. As these materials break down in the soil, nutrients become available to the plant. Often growers will add nutrients to their soil with compost, manure, or a manufactured chemical fertilizer to increase soil fertility. Ensuring nutrient availability to crops ensures that our food is abundant and nutritious.*

    - *We learned that nutrients in the soil must be absorbed in water so the roots can deliver them to the plants.* Discuss: *Do nutrients for humans need to be dissolved in water before we take them in?*
        i. Answer: Humans are a bit more adaptable in this way. Humans can take in dry food, but just like plants, our nutrients must be dissolved in water to be taken to our cells. We mix dry food with water in our digestive system if the food itself does not come with water! Plants do not have this capability. If there is no water available when the plant takes in its nutrients, no nutrients will be taken in.

6. *We can help to add and maintain nutrients in our soil in many ways. Farmers and gardeners will use nitrogen fixing plants, or plants that take nitrogen from the air and "fix" it into the soil, to add nitrogen to soils. We can also use many types of decomposed organic material to make compost. Adding this nutrient rich compost to the soil increases the soil's fertility.* (Learn more in the Bonus Cards on **Soil Organic Matter**, **Compost**, and **Mulching**).

7. Optional: Students can take compost from the garden and mix it with the loam created earlier to make an ideal vegetable growing soil.

- Discuss: *What about this soil we have made makes it ideal for many different plants?*

- *What is something you could do today to increase soil fertility in our garden?*
    i. Examples: Add scraps to the compost pile, incorporate compost into the soil, turn the compost pile to speed decomposition.

Connecting to the Garden

Note: This section requires a Three Sisters system actively growing in your garden or farm. If you would like to discuss companion planting but do not have the Three Sisters established, you can show pictures of this setup using the Three Sisters Graphic on page 9 of the Student Handouts.

Plants and food crops need different amounts of sunlight, water, and nutrients to survive and thrive. They are also impacted by what is growing around them. Think about how a densely packed forest may not have very many plants growing on the floor beneath the trees, whereas an open prairie is likely heavily populated with grass. This is due in part to the availability of light (and water) in these contexts.

Today we will look at how plants and food crops can be synergistic—or cooperate to produce a combined effect greater than the sum of their separate effects and support each other's growth. In agriculture, we call this intentional strategy 'companion planting.'

Let's look at a mature Three Sister Garden to observe the ways that plants work together. We will then play a Companion Planting Card Game to explore the ways that all plants work together to support one another's growing conditions in the garden.

Optional Activity #4: Three Sisters Garden Tour

Time: 5 minutes

Materials:

☐ Mature Three Sisters Garden consisting of squash, corn, and pole beans planted together

Optional:
☐ Student Handouts
- ☐ Three Sisters Graphic (page 9)
- ☐ Legends of the Three Sisters (pages 10-11)

Introduction:

Our food traditions are often deeply rooted in the people and places where they originated. Long oral and written histories in a variety of cultures give wisdom to following generations about how to grow and serve food that is good for the body and appropriate for the growing conditions of the area. Often foods that worked well in a certain area were integrated into cultural and spiritual traditions. One great example of a traditional companion planting garden is the Three Sisters Garden. This garden consists of corn, squash, and pole beans. This garden combination stems from an array of Native American and Indigenous cultures. Let's explore how the Three Sisters are adapted to one another for gardening and eating, and how they've been integrated into cultures.

Lesson:

1. Three Sisters in the Garden
    - Pole beans have a partnership with bacteria in the soil allowing them to take nitrogen from the air and put it into the soil, making the nitrogen available to other plants that need it. This can be a huge help to plants that need high amounts of nitrogen to grow, such as corn.

    - *What do you think corn does for beans to help them grow?*
        i. Answer: Corn provides a trellis for beans, keeping beans off the ground and decreasing the risk of rotting. A trellis also helps the bean plant produce a heavier harvest. As the beans grow through the tangle of squash vines and wind their way up the corn stalks into the sunlight, they also serve to hold the sisters close together.

- *Pay attention to the texture of the stem on squash. What do you think the squash does for its "sisters"?*
    i. The prickly stem and leaves on the squash are thought to help keep pests away from the garden, as raccoons and other pests may not like stepping on them.

- *Look at the broad squash leaves. How do you think the shade of the squash leaf on the group affects evaporation? What about weed control?*
    i. The squash serves as a living mulch, with the shade of the broad squash leaf at ground level helping to keep moisture in the soil (reducing evaporation) and blocking out the sun to control weeds.

2. Three Sisters for Nourishing our Body:
    - *A meal composed of the crops produced by the Three Sisters provides a complete meal for optimal human health. Corn and squash provide slow-release carbohydrates, while beans provide protein. The sisters are better together than when they are apart, as corn and beans provide complimentary amino acids that eliminate the need for meat, and the trio provides many micronutrients required so that humans can thrive.*

3. Three Sisters in Native American Cultures
    - *The Three Sisters are known as the 'Sustainers of Life' among the Oneida People. The botanical and nutritional partnership among these three plants have made them celebrated in many Native American cultures. We will now hear versions of the Legend of the Three Sisters.*
    - Ask two student volunteers to read the two Legends of the Three Sisters included on pages 11 and 12 of the Student Handouts.

Closing Discussion:

We've learned what our food crops need to grow, how they can work together, and some of what we can do to change their growing environments to help bring the food we want to our local climate. We've learned where different plants grow best and why, and how that influences diet choices culture around the world and throughout history.

As you go on with your day, think about a tradition that you want to start!

- What crops can grow in your local climate that also support the health of your family?
- Which of these crops do you love to eat, and how can you combine these foods to make a delicious new tradition?
- How could you better care for your soil to help these crops grow?

References

Teacher Background:

1. Plaster, E.J. (1991). *Soil Science and Management* (2nd Edition). Albany, N.Y: Delmar Pub.
2. Overstreet, L.F. and DeJong-Hughes, J. (2009). The Importance of Soil Organic Matter in Cropping Systems of the Northern Great Plains. *University of Minnesota Extension.*
3. Kohnke, H. and Franzmeier, D.P. (1994). *Soil Science Simplified* (4th Edition). Prospect Heights, Ill: Waveland Pr Inc.

Activity #1

Climate Map borrowed from Internet Geography (2015). Climate Zones.
Climate Zone Definitions taken from CK-12 lesson plans (2016). Chapter 2, Part 7 World Climates.

Activity # 2

Adapted from Bottle Biology and the Wisconsin Fast Plants Program: Build a TerrAqua Investigation Column *(option 1)*.

Activity #3

Basic background information borrowed from Kids Gardening.org: Soil Texture and Composition lesson.

Activity #4

Three Sisters Legends taken word for word from Northeastern State University, Three Sisters Legends.
Nutritional Background borrowed from the Oneida Nation: The Interworking of the Three Sisters.