The Horticultural Society of New York

GROWING WITH THE GARDEN: A CURRICULUM FOR PRACTICING HORTICULTURE WITH AT-RISK YOUTH

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Author:	**John Cannizzo**
Contributors:	**James Jiler**
Photography:	**John Cannizzo** **National Park Service**
Editors:	**John Cannizzo** **Alyssa Meyers**

How to Use this Guide

Almost every month, someone calls or sends me an email asking for information about gardening with at-risk youth: those who have been in trouble with the law, dropped out of school, and are disconnected from their communities, their families, and themselves. I work with at-risk young people all the time, and this guide is for individuals and organizations who want to help them out of seemingly hopeless situations and develop new and more complex ways of understanding and connecting to the world.

This guide is based on knowledge gained from the field: it is made up of the lesson plans and exercises I have used for the last dozen years. In teaching and in this guide, I put equal emphasis on developing students' practical skills through hands-on activities and improving their abilities to understand abstract concepts, use scientific reasoning, and perform applied mathematical calculations.

This curriculum is designed to be used over the course of the year, beginning in the winter months with chapters and exercises that can be applied indoors.

We start at the beginning: the earth and our environment. Many of the students in our program come from neighborhoods with very little green space, and have almost no concept of the natural world. In the first chapter, "Ecology," I introduce students to the big picture: our earth as an interdependent system that is increasingly under threat. Students learn about the features of their environment through hands-on exercises that ask them to identify land forms, see how trees clean the air, and understand landfills through excavation at the garden site.

From there, we turn to examine the plants that populate the surface of our earth and comprise a vital part of our environment. The second chapter, “Plants,” introduces students to the types of plants, their role in sustaining life, and their structure. Through observation, dissection, and description, students become familiar with leaves, petals, seeds, and fruits and learn the vocabulary necessary to identify them. This chapter also introduces the concept of photosynthesis, and includes exercises designed to scientifically demonstrate photosynthesis in action.

Plants need good soil, and Chapter Three, “Soil,” shows students the constituent elements of soil, introduces the ph scale and the differences between alkaline and acidic soil, and presents various types of soil amendments that will make the plants in the garden thrive. Through practical exercises of digging in the garden and conducting soil tests to see what amendments are necessary, students learn how to prepare the garden for planting.

Next, we tackle the critical task of planning the garden in Chapter Four. Before planting, it is essential to design the garden space. This chapter introduces scale drawing, the difference between shade and sun, and the importance of placing plants correctly in the garden so that they will thrive. Students create a scale drawing based on their observations of the garden site.

In Chapter 5, “The Vegetable Garden,” students implement the plans they have developed in the previous chapter as they learn of the various vegetable types and varieties. This chapter sets out the principles of organic gardening, and details the ongoing maintenance tasks necessary to keep the garden thriving. Exercises from calculating seed and space requirements to seed germination teach students the necessary steps to create a vegetable garden.

Chapter 6, “The Pollinator Garden,” introduces students to the bees, butterflies, and moths that make gardening possible. The students encounter the principle of co-evolution, and see the scientific method in action as they learn of the scientific discoveries that revealed the hidden links between insect pollination and plant propagation. Through exercises requiring observation and description, they uncover the differences between wind-pollinated flowers and insect-pollinated flowers, and learn to identify the features of bees, butterflies, and moths.

Finally, we turn to indoor planting in Chapter Seven, which details the benefits and challenges of greenhouse gardening. Students learn about the different types of greenhouses, how to set up a greenhouse, prepare indoor soils, create and maintain indoor plantings, and deal with garden pests and diseases. Practical exercises allow students to understand seed anatomy, create indoor soil, and germinate seeds indoors. When spring comes, you will be ready to begin your garden again.

This curriculum offers students an introduction to the basic skills of horticulture, but more importantly, offers them the benefits of horticultural therapy as they learn the rhythm of the seasons and the natural world and connect more deeply with their environment. When we take control of our behavior we also grow stronger. But this requires a close observation of ourselves. Horticulture can help us. Horticulture is observation. That is the whole purpose of this curriculum guide—to help the student to learn to observe: to observe in the moment and live in the moment. This intense observation causes the gardener to become calm; blood pressure to drop; anxiety to gradually subside. In the beginning, students ask the same questions: How often should I water my plant? What is the name of that plant? The answer to the first is that you must water your plant when it is thirsty—and you will know when it is thirsty by observation of its appearance and of the appearance of the soil surrounding it; the number of rain days in the last week; the season of the year and the angle of the sun. The answer to the second question is that the name of the plant is not important and of no use to you until you see that plant as an individual.

When a student first enters the garden, his impression of it is of a vast green undifferentiated thing. Only gradually will the plants begin to identify themselves. When it is possible for the students to turn their back on a plant and describe it, then it is time to know the name of that plant. I have seen it happen again and again that at first a student learns by rote. This may go on for weeks or longer, depending on the student. One day, however, the student will suddenly awaken to observation. At that point, what took a week to learn can be learned in a day. What took a day to learn can be learned in an hour. This begins the second stage of the learning, which is the long-term commitment. Horticulture and agriculture takes a lifetime to understand. But the slow growth of plants is designed to engage the farmer or gardener in the process as a long-term partner. Developing a conscience is the end product of all life skills training. When the gardener or horticulturist or farmer takes on the responsibility in a real way for the well-being of 1000 or 10000 plants, it is only with a conscience that they can fulfill that obligation.

The most important fact of all—and there is no more important aspect of learning horticulture—is that a plant is a living thing and the student of horticulture is in a select community with the doctor and the veterinarian. He/she is a caretaker taking care of a living creature. It is a very powerful experience for a student that may have been under the care of a foster parent or home, in a rehabilitation program, or a recipient of assistance for much or all of their lives to now take on the role of caretaker. They will suddenly find themselves in the position of distributing food to a community from the farm that they have cared for. Conscience, responsibility, caretaking: they grow as the garden does.

Chapter 1: Ecology

Performance Objectives

Students will be able to:

- Explain the basic components of our environment.
- Correctly identify and record land masses in their area.
- Correctly identify the role of environmental science in managing natural resources.
- Identify the parts of at least one ecosystem that is found in their area.
- Explain how pollutants enter the environment.
- Explain the importance of recycling.
- Explain how natural systems eliminate waste.
- Explain the importance of the hydrological cycle.
- Explain the role of plants in purifying the air that we breathe.

Assessment will be based on several criteria:

- The student will prepare a portfolio of local land forms.
- The student will make a worm bin.
- The student will perform experiments to show how plants respire.
- The students will assist in the clean-up of a site in preparation for planting a garden.

Lesson
1 - 1

SKILLS

Basic geology

Cooperation

Photography

Recording

Research skills

Working together as a group

VOCABULARY

Biosphere

Composted

Decomposed

Ecology

Erosion

Fungi

Micro-feeders

Natural resources

Predators

Remediation

Help Keep Your World Beautiful

The backyard of the daycare center where HSNY's interns are working used to be a parking lot. Before there was a parking lot, there was a building. The building was demolished after an arson, and the refrigerators, sinks, bathtubs, closets full of clothes, utensils, dishes, televisions were all put into the basement and covered with a few inches of "clean fill." Now interns will plant big trees where the building used to stand. Baltazar, Zaid, Danny and Lorenzo unearth a huge slab of concrete, which must weigh at least 200 pounds.

There is often little or no real soil in areas where buildings have been demolished or where there is massive land fill. Huge chunks of concrete lie buried just below the surface

I urge them on to use levers and speak about Archimedes to bewilderment. They try the levers. Baltazar organizes the project because he has many ideas about how it "should be"; Lorenzo bears the burden; Danny doesn't understand; Zaid holds the shovel but is not lifting. Everyone is talking at once. As the slab gets closer to the top of the hole, it gets harder to move. As the amount of space between the bottom of the hole and the bottom of the chunk increases the burden grows proportionately heavier. It totters back into the hole.

Zaid holds his shovel as if nothing is happening. Danny uses his shove totally ineffectually, and Baltazar jumps away, not so much dropping but throwing his shovel. His face is a mask of fear he looks at Lorenzo. Lorenzo assumes the entire weight.

"Ugh, but, if, then," Lorenzo says, and with superhuman effort hoists the stone.

"Help him," I shout. Everyone wakes up except Baltazar, who remains frozen.

That chunk of debris goes into the dumpster.

In removing the slab and other debris from the lot, the interns discover the importance of teamwork and their vital role in caring for the environment. Now that the ground has been cleared, we can plant the trees that will revitalize the site and improve the local ecosystem.

The Environment

Everything that affects and surrounds us is a part of our environment. The environment is made up of the things we can see, hear, feel, touch, and smell. It is time for the people of the United States and perhaps even the world to roll up their sleeves and ask, “How can I Help?” Just as the oceans of our world are made of individual droplets of water, so each individual contribution to lessening the production of trash and litter can add up to make an ocean of difference.

The majority of the population disposes of its trash in the proper manner. We throw our trash into the receptacle, we flush our toilets, and haul large debris to the city dump. Our industries load their toxic waste into the proper receptacles and ship them off to some graveyard for toxic and nuclear waste. And then we go about the business of creating more. More household trash, more toxic and nuclear waste, more chemicals, more cars, more of all kinds of things that will eventually end up as trash.

Waste disposal has produced some serious problems for all of us. Landfills are over flowing. Garbage buried years ago is still lurking just below the surface. We don’t know how to make those canisters full of nuclear waste disappear so the mountain just keeps growing. In recent years, we’ve watched as a bombardment of disposable materials became available on the market. Disposable diapers, plates, cups, flashlights, cameras, etc. have all piled up be added to the heap of trash which already litters the landscapes and oceans. We have so much trash that we don’t know what to do with it all. So we try to ship our garbage to other parts of the country or world to be buried in someone else’s backyard.

This was the case of the Mabro, a sea vessel that left New York Harbor on March 22, 1987. It was loaded with 3,168 tons of solid waste in the form of garbage and chemicals produced by the residents and commercial businesses of Islip, Long Island and other New York townships. Its destination was Jones County, North Carolina.

Upon the Mabro’s arrival at Jones County, the residents changed their minds. They too had more garbage than they needed and they weren’t about to receive any more. The ship began a search for a township or country that would accept Long Island’s smelly trash. Four states and two counties turned away the barge. On May 16, after 162 days at sea, Mabro, now nicknamed GAR-BARGE, returned to New York Harbor still carrying its smelly cargo.

Suggested Activity

Encourage discussion as to whether the garbage on Mabro should be accepted. Let them debate the pros and cons of their decision.

There are no easy solutions to the problem of waste disposal. It may be a problem for which we will have to contend with for the remainder of human existence. We can, however, begin to reverse some of the damage done by learning to care for our environment and by becoming wise consumers. By recycling, reusing, and reducing we can reduce the amount of pollution we produce each day and that can make a difference to the environment as a whole.

Ecology and Natural Resources

The United States is rich in natural resources, fresh water, wildlife, rich soils, and forests. Not only the urban areas, but also the whole of the United States is faced with environmental problems that threaten these resources. Water pollution, acid rain, over-full landfills, and air pollution are just some of the environmental issues that our nation must address.

We have made ample changes to the environment that we share with plants and animals. With the invention of tools and other modern technologies, we have created a world more comfortable for ourselves and our communities. But our wish for a better standard of living is contingent on our natural resources.

The changes made to achieve these higher living standards have not been without harmful effects on the plant and animal population. Some of the changes have even produced negative effects for some people. With the building of cities and the invention of cars and highways, we have created threats that have affected the wildlife population and their habitats.

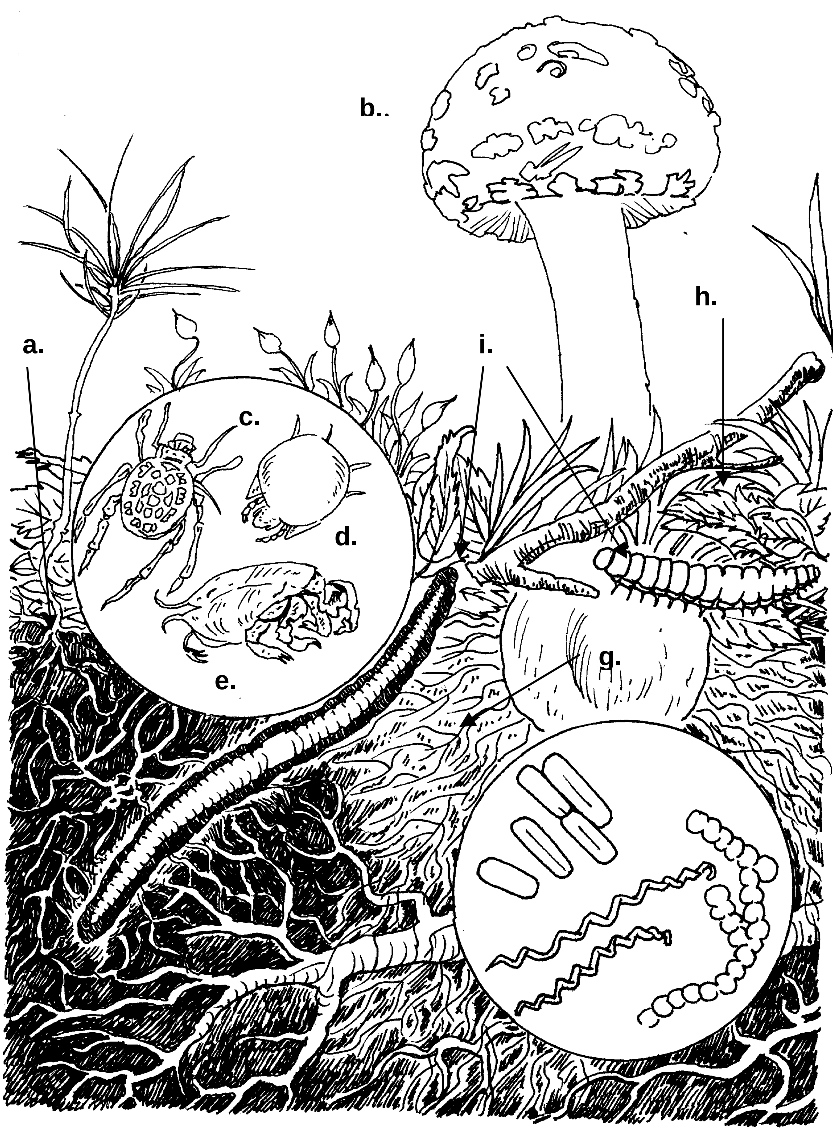


Fig. 1. Forest ecology is just one of thousands of complex ecosystems on earth.

a. More research is needed to learn how mycorrhizal fungi mediate interaction among different tree species. A fungus forms a mycorrhizae with one tree, then extends its hyphae into the soil and forms mycorrhizae with surrounding trees. This directly links the trees to each other.
b. Some fungi like toadstools have hundreds of underground threads. They take nutrition from tree roots and in turn make soil more fertile.
c. Mites are a diverse group of microbial feeders. 1 square meter of forest can support 200 thousand individuals.
d. Some mites dwell in leaf litter.
e. Microfeeders attain high numbers in forest areas.
f. Millipedes grazing on pine needles mix the plant cells with bacteria in their own guts.
g. The main part of the fungi are the underground threads.
h. The important leaf litter layer.
i. Cyanide produced by the millipedes' surface cells used to defend against predators is a regulator of forest nutrition cycles. Worms drag fallen leaves underground where they rot and release nutrients.

We have relied on the resiliency of planet Earth to conform to the changes we make and to repair itself no matter what we do to it. We are now beginning to realize that this is not true. We now understand that our natural resources—land, water and air—need our protection and safe-keeping. We see that if nature's balance is to be restored, then we need to make changes to our lifestyle in order to help.

The purpose of this unit is to sensitize students to the value of Earth's natural resources and to encourage them to share in the responsibility for its care. By the conclusion of this unit, we hope they will form an enduring relationship with their environment.

HSNY students and interns will begin this study by looking at the ecosystem and how plants and animals have adapted to the conditions of their environment. They will see that the ecosystem is a complex community where trees, plants and animals are dependent upon each other for survival. By studying several types of environmental concerns affecting these ecosystems, students and interns will come to understand the fragility of the ecosystem.

An ecosystem is created when plants and animals adapt to the type of soil, land forms, and climate of an area. The wide variety of soils, land forms, and climates have created a great many ecosystems in the United States and across the planet.

The areas on or near the surface of the planet, where plants, animals, and humans can survive is the biosphere. It is a thin photosensitive film of life. If the earth were the size of an egg, the biosphere would be no thicker than the shell, even including the deepest oceans. This layer constantly receives impressions from the sun and the moon and in turn constantly sends out impressions to the life forms that dwell upon it, so taken as a whole, the biosphere could be considered the largest living organism on our earth. In the biosphere, many different species of plants and animals survive in special environments called habitats. Many of these habitats overlap, leading the species to dependent upon one another for survival and thus creating a unique biological community.

As we begin our study, we will look at several features of the ecosystem. This will include a study of 1.) land forms, 2.) soil, 3.) the hydrologic cycle, 4.) vegetation, and 5.) climate. We will learn how all these features depend on each other for the survival of the ecosystem. We will explore the negative effects of land pollution by solid wastes and chemicals, water pollution through the dumping of trash and hazardous materials, and the effects of acid rain, a combination of air pollutants and water vapor. Students will learn some of the current solutions to these problems and will be asked to create some of their own solutions. By posing and answering a series of theoretical questions, they will come to understand that the answers to environmental questions are not always so easy to settle.

Finally, it is hoped that each student will see the small part that the individual plays in solving Earth's environmental problems and will implement changes in their lives that will lessen the negative impact of pollution on planet Earth.

Though this lesson is paginated as chapter 1, it, like many of the other lessons, is meant to be taught throughout the year. Through the hands-on experience of gardening and the use of books, discussions with community members—especially older members, experiments, and observation, students will gain some basic information on each topic. Much of the learning will be experiential, including environmental remediation projects and garden installations that will provide hands-on experiences. This approach through real-life experience will allow the students to share their ideas and concerns with each other and the community in general. Our culminating activities will be to transform neglected spaces into green spaces, improve the canopy over our city street by planting trees, and write about and create video and photographic records of the process of transformation.

With our objectives firmly planted in our minds, we're on our way to take a look at land forms.

Land forms

Land forms are the distinctive topological features of the earth, like hills, valleys, rivers, and ponds. Natural forces such as ice, fire, and wind shape these land forms. The surface of the earth is constantly being refashioned as these forces modify its the topological features.

Erosion is a natural process by which the soil and rocks of earth's surface are constantly scraped and worn away. Flash floods can erode tons of soil in a short period of time. The soil can be carried many miles away from its original point and deposited elsewhere, building up new land.

Huge masses of ice, called glaciers, can act like massive filing boards, eroding existing land forms and flattening the landscape. They shift rocks out of their paths as they move, while rocks below the surface are broken up and carried away. Glaciers create moraines, large mounds of gravel, sand, and clay.

Earthquakes and volcanoes can move land and cause much destruction. The shifting of solid plates of rock under the earth's surface causes islands and mountains to disappear and new land forms to be built up. Volcanoes spew lava, which hardens, modifying the topography.

Suggested Activities

1. Whenever working in various locations, handle soil. Encourage students to compare the textures, colors, and odors of soil.

2. When watering observe the soil. Is it sandy? Does it contain clay? Is it loamy? Let students observe which kind allows the water to drain through first.

3. Look for signs of birds and other animals as you create your gardens—which animals begin to appear and which to disappear.

4. Always discuss how people use the land. Discuss the effect that land use by humans has on the environment. When digging near newly constructed buildings, notice the high volume of construction debris. Compare it to the relative scarcity of construction debris at sites containing older structures. What does this say about present day material use? What does it say about the preparation of garden areas at older sites? What about the relation of labor to materials at older sites vs. newer construction sites?

5. Discuss how trash and litter deface the appearance of planet Earth and their neighborhood. Constantly emphasis cleaning up. If you are working at a school, public space, or private space, consider installing signage to educate neighbors to keep dogs out of tree pits, pick up after dogs, and dispose of trash properly.

6. Locate where hazardous waste is produced and disposed of in your community.

7. Locate gas stations in your area with an oil recycling program.

8. Search the internet for an ecology tip of the month.

9. You should constantly be looking for ways to fund tree planting in the sidewalk, at schools, and in public spaces.

10. Learn the recycling schedule at all the sites where you are active. Contact the Parks Department to find out about collecting branches and limbs pruned from trees and how to bundle them if you live in an Asian longhorn beetle quarantine area.

Exercise
1 – 1

STUDYING LAND FORMS

Objective:

To teach students to observe and identify various land forms found in their area.

Materials:

- Digital camera
- Portfolios with plastic pages to hold photos

Procedure

1. Observe the different land forms in each area that the group is working. Look for woods, river, hills, etc. Discuss how the animals and plants use the land. Look to see how man has changed the landforms (i.e., added buildings and parking lots).

2. Make sure that each member of the group visits as many different sites as possible. Discuss the similarities and differences between the land forms at sites in various areas and those around the neighborhood.

3. Have the students recall the landscape later on from memory. Discuss the size and shape of each of the garden sites and compare the differences and similarities of the terrain and exposure to sun as well as the surrounding man-made structures.

4. Share a digital camera, video camera, or even a mobile phone camera to record the various sites.

5. Have the students create a portfolio depicting various land forms and plant life at the sites where you are active. Ask them to organize the portfolio by various criteria: all sites near water; all sites with wooded areas; all sites with changes of elevation. Collect a comparative portfolio of man-made sites such as rooftop gardens and landscaped courtyards.

6. In urban areas there are many birds. Discuss the differences in various birds and learn about the ways that they make their homes. How have birds like pigeons adapted to man-made structures?

Lesson
1 - 1

Exercise 1

SKILLS

Basic understanding of land forms

Creating a portfolio

Organizing and separating

Photography

Working from memory

VOCABULARY

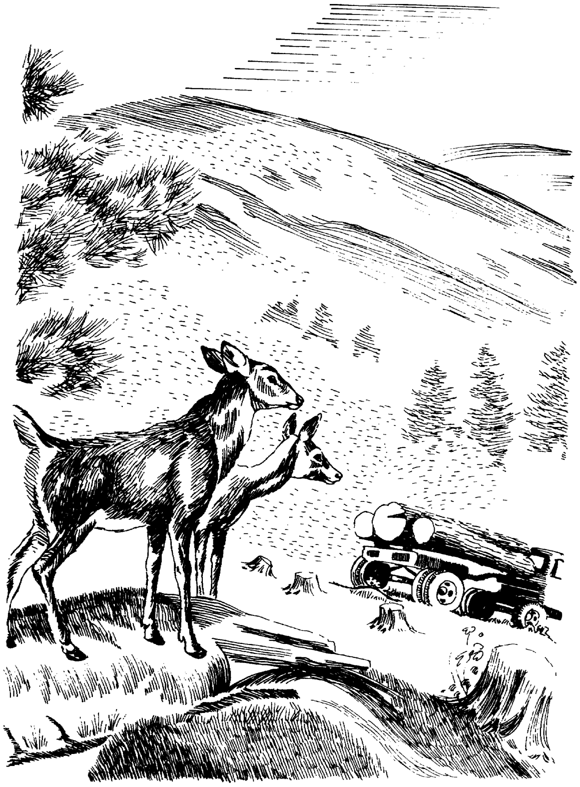
Ecology

Elevation

Environment

Land form

Terrain



Forests and Other Vegetation

Once the United States was covered with forests that covered most of the country. Forests at one time grew so thick that a person could not walk through them. With the arrival of the European settlers and the development of land for cultivated crops, farms, towns and cities, these forests were cut down and the land cleared. Cultivated crops now replace those areas where natural plants once grew. Alaska and Hawaii are the only two states that still have a substantial amount of their natural vegetation.

Types of Forests

The kind of forest found in an area is determined by the climate, soil, and topography of the region. Natural forest will maintain itself in a relatively fixed, self-regulated condition for extended periods of time. The size and height of the plants in a forest control the type of vegetation which will grow on forest floor. Forest fires and harvesting of trees by lumber companies may cause a forest to change from one type of tree to another.

Tree Groups

Based on the type of leaf and climate, forests in the United States have been divided into the following groups:

Deciduous trees are found usually in the eastern United States. They are broadleaf trees with a wide, flat leaf. Their wood is hard and their seeds are enclosed in some type of covering. These trees include the oak, maple, and poplar.

Coniferous trees are found in the more northerly forests of the United States. Coniferous trees have needles or scale-shaped leaves and are called evergreens. Much of the softwood yielded in the United States comes from the Douglas fir forest of the Pacific Northwest. The seeds of the coniferous trees are found between the scales of the cones produced by these trees. Coniferous trees include the pine, fir and spruce.

Palm trees flourish in warmer climates, including some desert areas of the United States. Since they do not have branches, the leaves grow right out of their trunks.

Many plants and animals depend on trees for food and shelter. A small elm tree can be home thousands of different species of plants and animals. Birds survive on the insect population they find in the trees, while animals build their homes in these same trees.

People also need trees for survival. Trees give us the wood we need to build houses, make furniture and instruments, and many other objects. We heat our homes with the wood from trees. In some countries, the only fuel people use is wood. Trees provide us with fruits, spices, and nuts. Paper is made from trees.

Trees help to lessen the amount of dust in the air by capturing it in their leaves. They take in carbon dioxide and release oxygen which is necessary for all life. The roots of trees act as a net or web, holding the soil in place.

The natural growth pattern of a forest is more conducive to animal life than a man-made forest. Forests planted by humans, tree plantations, tend to have trees of the same age and are planted too close together. The size and closeness of the trees block out light and deters the growth of ground plants. The thick clusters of fallen needles and leaves discourage the growth of new trees. Dead trees, which in a natural setting would rot and become home to insects and fungi, are cleared away. Thus the biological diversity that would exist in a natural forest does not exist in tree plantations.

Other Suggested Activities

1. Let the students make a worm bin and cultivate red wigglers to observe how they turn organic waste into compost. Harvest your work compost and spread it on planting beds. The directions are given on the next page.

2. Let the students observe fungus in the garden. Place a piece of moistened bread in a plastic bag. Place it in a warm, shady place. The fungus grows quickly with a display of beautiful colors and forms. Students should examine it every day. Soon the bread will disappear and the fungus will die.

3. Whenever making a lawn, let the students grow grass people to give to children. Fill a small flower pot with soil. Add left-over grass seeds on top and water. Place in a sunny place. As the grass grows, the students can cut or style the “hair.” They can create a face on the pot with various art materials.

4. Let the students grow trees from seeds. Find a brown pine cone which is beginning to open. Shake off the seeds and plant in a pot filled with soil. Water it and then keep it moist. A pine tree should sprout in about three to four weeks. Do the same with apple seeds, maple samara, acorns, peach pits and other tree seeds (gather fruit seeds from organic fruit or from fruit grown in local gardens).

Pollution and the Importance of Recycling

Living things are harmed and/or killed by pollution. Plants, trees, and animals die from pollution. Buildings are damaged and humans are made ill. These are just a few of the side effects of pollution.

Solid Waste

Solid waste is made of solid or semi-solid materials. They are usually the remainder of human or animal activity. It is unwanted, worthless, and may also be hazardous.

Solid waste can be categorized as the following: 1.) Garbage which is the decomposable waste from food. 2.) Rubbish which is made primarily from noncombustible waste such as metals and glass; combustible waste such as paper, wood and fabric; and other non decomposable wastes. 3.) Sewage treatment solids which is composted of materials caught on sewer screens, settled solids and sludge. 4.) Industrial wastes which include paints, sand, and chemicals; 5.) Agricultural wastes such as crops residue and animal manure, 6.) Mining waste contributes coal and lug heaps to the solid waste collection. Dead animals, ashes, debris from construction sites, fallen trees and limbs are other forms of solid waste.

The most commonly used method to dispose of solid waste is on land. Solid waste makes up more than 90% of the nation’s public waste.

Currently, garbage is being produced at an alarming rate. In the United States we create about ten pounds of plastic each year for every person on Earth. One thousand four hundred pounds of trash per person per year is produced by Americans alone. Americans discard three million cars per year, use fifty percent of paper for packaging alone, and our industries produce nearly two hundred fifty million tons of toxic, corrosive and ignitable refuse. At the current rate of production, it is evident that we will run out of places to store our trash in the very near future.

Exercise
1 – 2

TREES AND THE AIR WE BREATHE

Trees help to keep the air we breathe clean and healthy to breathe. Tiny holes in the leaves of trees called stomata allow the tree to breathe through them and to “sweat” out water. Trees absorb carbon dioxide from the air and give off oxygen which people, animals, and other plants need to breathe.

Objective:

To teach students how plants help to keep the air clean and healthy to breathe.

Materials:

- A tree seedling gathered in the field or germinated from an acorn, maple samara or other easy to germinate seed for which you will need:
- Soil
- Pot
- Seed or seedling
- Large clear plastic bag
- Rubber band or string.

Procedure

1. Discuss how trees help to clean the air.

2. Have the students water tree seedling and place them in plastic bags. Secure the bag in place with a string or rubber band. Moisture from the tree will condense in the bag.

Lesson
1 - 2

Exercise 2

SKILLS

Basic understanding of botany

Conducting a simple experiment

Observation of natural phenomenon

VOCABULARY

Carbon dioxide

Oxygen

Samara

Seedling

Stomata

Landfill

Around 1920, the land filling of wetlands began. Incinerators, which had previously been the primary method of waste disposal, came under attack for causing air pollution. Land filling was proclaimed a safe and sanitary solution for the problem of waste disposal. Land fills were to hold garbage and waste until it decomposed. Waste that would not decompose was buried out of sight in land fills in alternating layers of garbage and dirt.

Three hundred new landfills were built per year across the country during the 1970s. With an increasing awareness of recycling, the creation of new landfills has diminished to somewhere between fifty to two hundred per year according to the National Solid Waste Management Association. But even if the current rate of garbage production remains the same, we will eventually run short of landfill space.

Not only are landfills reaching their capacity, but poisonous substances are leaking into our water supply. Older land fills were constructed without linings. This has allowed chemicals from manufacturing plants and factories to seep into the underground water. Leachate, a liquid produced by rotting garbage, has also seeped into the aquifers or ground water. These pollutants end up in wells and the water supply.

We are also discovering that burying our trash does not get rid of it. Many of the items we bury in our landfills are not biodegradable and the lack of air hinders the decomposition of waste. This means that some of these items, such as Styrofoam, will still be in a landfill some two hundred years from the day they were buried.

The backyard of the Bed-Stuy Campaign against Hunger was literally buried under a mountain of construction debris from the renovation of the building.

It required 2 canisters of 20 cubic yard capacity each to haul away the debris. After soil testing and soil remediation, the lot was finally able to support an urban farm.

Exercise
1 – 3

UNDERSTANDING LANDFILLS

Objective:

To give students firsthand experience with the problem of an overabundance of trash.

Materials:

- Wheelbarrows
- Shovels
- Debris. As you begin to restore an environmentally damaged area, you will find yourself confronted with an array of construction debris if you are working in an urban area where a previous structure was demolished to make way for a new structure. This debris forms the materials of this lesson.

Procedure

1. Several days before you are ready to do a major cleanup or remediation at a new site, have the students read the narrative on landfill found above.

2. As you dig into a neglected or newly-cleared space, notice the different classes of material.

3. Separate material by the usefulness of the material, its ability to decompose, or its organic quality.

4. Explain to the students that whatever cannot be recycled must be placed in the landfill. Emphasize that stone, gravel, and sand are recyclable and may be of use in your gardening work as substrate for pathways or aggregate for concrete footing for fence posts or vertical garden structures. Used brick is a valuable commodity. Large stones and boulders not only are attractive garden ornaments, but also are very good for team-building exercises because they take enormous effort to dislodge.

5. Have the students create different piles of material based on useful ness. All plastic must be disposed of as it cannot decompose.

6. Suggest that they consider which items have been needlessly placed in the landfill. Calculate the cost of hiring a carting service to remove the debris.

Lesson
1 - 3

Exercise 3

SKILLS

Calculating costs

Discriminating among materials

Factoring usefulness

Recycling

Working as a team

VOCABULARY

Aggregate

Commodity

Debris

Decompose

Environmentally

Landfill

Recycle

Remediation

Restoration

How to make a Worm Bin

Composting with redworms is great for apartment dwellers who don't have yard space, or for those who don't want to hike to a backyard compost bin with their food scraps. Some kids like to keep worms for pets! By letting worms eat your food wastes, you'll end up with one of the best soil amendments available—worm castings. This is the cheapest and easiest to manage worm bin system that I've seen:

Materials Needed to Make an Easy Harvester Worm Bin:

- Two 8-10 gallon plastic storage boxes (dark, not see-through!) as shown in pictures Cost: about $5 each
- Drill (with 1/4" and 1/16" bits) for making drainage & ventilation holes
- Newspaper
- About one pound of redworms

Step 1 Drill about twenty evenly spaced 1/4 inch holes in the bottom of each bin. These holes will provide drainage and allow the worms to crawl into the second bin when you are ready to harvest the castings.

Step 2
Drill ventilation holes about 1 – 1 ½ inches apart on each side of the bin near the top edge using the 1/16 inch bit. Also drill about 30 small holes in the top of **one** of the lids.

Step 3
Prepare bedding for the worms by shredding newspaper into 1 inch strips. Worms need bedding that is moist but not soggy. Moisten the newspaper by soaking it in water and then squeezing out the excess water. Cover the bottom of the bin with 3-4 inches of moist newspaper, fluffed up. If you have any old leaves or leaf litter, that can be added also. Throw in a handful of dirt for "grit" to help the worms digest their food.

Step 4
Add your worms to the bedding. One way to gather redworms, is to put out a large piece of wet cardboard on your lawn or garden at night. The redworms live in the top 3 inches of organic material, and like to come up and feast on the wet cardboard! Lift up cardboard to gather the redworms. Or, if you wish to purchase worms, HSNY can give you names of suppliers in NYC. An earthworm can consume about 1/2 of its weight each day. For example, if your food waste averages 1/2 lb. per day, you will need 1 lb. of worms or a 2:1 ratio. There are roughly 500 worms in one pound. If you start out with less than one pound, don't worry—they multiply very quickly. Just adjust the amount that you feed them depending on your worm population.

Step 5
Cut a piece of cardboard to fit over the bedding, and get it wet. Then cover the bedding with the cardboard. (Worms love cardboard, and it breaks down within months.)

Step 6
Place your bin in a well-ventilated area such as a laundry room, garage, balcony, under the kitchen sink, or outside in the shade. Place the bin on top of blocks or bricks or upside-down plastic containers to allow for drainage. You can use the lid of the second bin as a tray to catch any moisture that may drain from the bin. This "worm tea" is a great liquid fertilizer.

Step 7
Feed your worms slowly at first. As the worms multiply, you can begin to add more food. Gently bury the food in a different section of the bin each week, under the cardboard. The worms will follow the food scraps around the bin. Burying the food scraps will help to keep fruit flies away. What do worms like to eat? Feed your worms a vegetarian diet. Most things that would normally go down the garbage disposal can go into your worm bin (see the list below). You will notice that some foods will be eaten faster than others. Worms have their preferences just like us.

Feeding your worms:	
Worms Love	Worms Hate
Breads & Grains Cereal Coffee grounds & filter Fruits Tea bags Vegetables	Dairy Products Fats Meat Feces Oils

When the first bin is full and there are no recognizable food scraps, place new bedding material in the second bin and place the bin directly on the compost surface of the first bin. Bury your food scraps to the bedding of the second bin. In one to two months, most of the worms will have moved to the second bin in search of food. Now the first bin will contain (almost) worm free vermicompost. (You can gently lift out any worms that might remain, and place them in the new bin, or put them into your garden!)

Troubleshooting		
Problem	**Probable Cause**	**Solution**
	Too wet	Add more bedding
Worms are dying or trying to escape	Too dry	Moisten bedding
	Bedding is used up	Harvest your bin
	Not enough air	Drill more ventilation holes
Bin stinks!	Too much food	Do not feed for 1-2 weeks
	Too wet	Add more bedding
Fruit flies	Exposed food	Bury food in bedding

Where to get worms:

Worms are available from the Lower East Side Ecology Center in East River Park, NYC, NY.

More Suggested Activities

1. Let students get into the habit of reusing plastic cups. Try to see how long each student can maintain his or her paper or plastic cup or utensil. Collect plastic water bottles for use as watering bottles when seed starting.

2. Show the students how worms work as decomposers. Fill a large clear plastic container about half way with dirt. Moisten the soil and place red worms in the soil. Place several different uncooked food items on top of the soil. Cover the container to lock in the moisture and allow the students, to observe what happens. Let them record the results in their eco-journals.

3. Using the dirt from your worm experiment allow the students to start seeds in the worm soil. Explain how the decomposed organic matter is a natural fertilizer.

Water Ecology

Water is the most common substance on earth. It covers three-fourths of the earth's surface, is the main ingredient in most fruits, vegetables, and meats, and comprises 65% of the adult human body. Three quarters of a person's body weight is made of water, while blood consists of 90% water.

Water improves human life in a variety of ways. Without it, people would die within a few days. With it, we water our crops and add variety to life through swimming, water skiing, and other recreations. We use water to clean ourselves and the environment in which we live.

Water is the only element known which occurs in all three states of matter: 1.) liquid, the most common, 2) a solid (ice) and 3) a gas or vapor. As ice, water will float because of the air it contains, which makes it lighter than water. It is found as glaciers, ice caps, hail, snow and frost. As a liquid, the molecules are able to slip and slide around each other, for they are more loosely bound together. Water in this state is found as rain droplets and dew. As a vapor, the molecules move very rapidly and have little attraction to each other. It is during this state that water evaporates. It is evaporation that causes puddles to disappear while an excess of water vapor in the air causes the air to feel "sticky." As a gas or water vapor, it is fog, steam and clouds.

Freshwater makes up only about three percent of the water found on planet Earth. This is the water used by plants, animals, and humans. Freshwater is found in rivers, lakes, ponds, and streams. Researchers have spent much time developing methods of removing salt from seawater as the demands for freshwater have increased. The major problem is the cost of the desalinization process.

The Hydrologic Cycle

The water on planet Earth is not new. Water is constantly in motion changing from a vapor (gas) to a liquid (rain) to a solid (ice, snow). It travels continually from the earth to the atmosphere (shown in figure 3).

During this cycle, water evaporates from the ground, vegetation (via transpiration), and other bodies of water (lakes, rivers, streams, etc.) It travels through the atmosphere as a vapor, where it cools and condenses. The droplets join together to form clouds. Rain falls back to the earth from these clouds, feeding the earth's surface and making it possible to support plant life. Lakes, streams, and rivers are fed by these rain waters. Underground cavities, called aquifers, catch some of the rain water as it seeps into the soil. Soil moisture, which is part of the water that has been absorbed into the soil, is taken up through the roots of vegetation and is transpired from the leaves. The water from these sources is heated by the sun and returns to the atmosphere as a vapor. Thus water constantly travels from the ground to the atmosphere and back to the ground.

The hydrologic cycle has no beginning or end, but is a constantly moving system. No water is ever lost or gained in this cycle for it simply returns to the earth in one form or another. This cycle plays a major role in determining climate and types of vegetation, so what affects this cycle at any point can have long-lasting consequences.

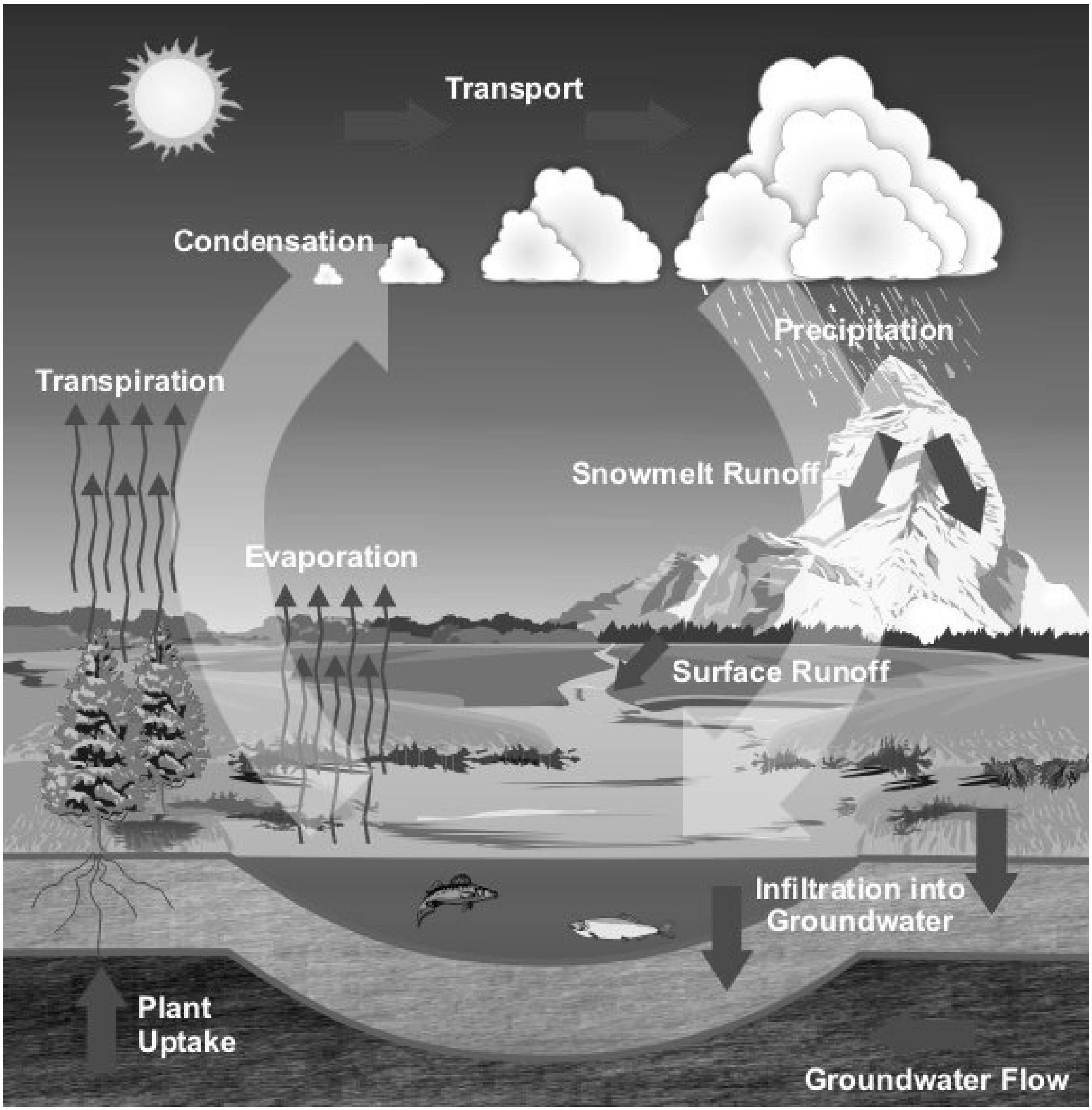


Fig. 3. The Hydrologic Cycle

Understanding the relationship between Air and Water

Cumulus: In Latin, this means "heap." Cumulus clouds look like a heap of cotton balls or whipped cream. There are many cumulus clouds, and some can be predictors of wet weather approaching.

Altocumulus may appear as parallel bands (top photograph) or rounded masses (bottom photograph). Typically a portion of an altocumulus cloud is shaded, a characteristic which makes them distinguishable from the high-level cirrocumulus. Altocumulus clouds usually form by convection in an unstable layer aloft, which may result from the gradual lifting of air in advance of a cold front. The presence of altocumulus clouds on a warm and humid summer morning is commonly followed by thunderstorms later in the day.

Altocumulus Cloud

Fair weather cumulus have the appearance of floating cotton and have a lifetime of 5-40 minutes. Known for their flat bases and distinct outlines, fair weather cumulus exhibit only slight vertical growth, with the cloud tops designating the limit of the rising air. Given suitable conditions, however, harmless fair weather cumulus can later develop into towering cumulonimbus clouds associated with powerful thunderstorms.

You have only to look up into the sky to try your luck at weather forecasting. Clouds give us a clue about what is going on in our atmosphere and how the weather might change in the hours or even days to come. Each type of cloud forms in a different way, and each brings its own kind of weather.

Cool Condensation

Clouds are water. As you probably know, we can find water in three forms: liquid, solid and gas. Water as a gas is called water vapor. Clouds form when water vapor turns back into liquid water droplets. That is called condensation. It happens in one of two ways: when the air cools enough, or when enough water vapor is added to the air. You've seen the first process happen on a summer day as drops of water gather on the outside of a glass of ice tea. That's because the cold glass cools the air near it, causing the water vapor in the air to condense into liquid. Unlike the drops on the side of your glass though, the droplets of water in a cloud are so small that it takes about one million of them to form a single raindrop. Most clouds form this way, but the cooling comes not from ice in a glass, but as the air rises and cools high in the sky. Each tiny cloud droplet is light enough to float in the air, just as a little cloud floats out from your breath on a cold day.

Too Clean for Clouds?

Our air has to be just a little bit dirty for clouds to form. That's because water vapor needs a surface on which to condense. Fortunately, even the cleanest air has some microscopic particles of dust, smoke or salt for water droplets to cling to, so the air is rarely too clean for clouds to form.

Fair weather cumulus cloud

Stratus: It's Latin for "covering" or "blanket." Stratus clouds look like a flat blanket in the sky.

Nimbostratus are dark, low-level clouds accompanied by light to moderately falling precipitation. Low clouds are primarily composed of water droplets since their bases generally lie below 6,500 feet (2,000 meters). However, when temperatures are cold enough, these clouds may also contain ice particles and snow.

Stratocumulus clouds generally appear as a low, lumpy layer of clouds sometimes accompanied by weak intensity precipitation. Stratocumulus vary in color from dark gray to light gray and may appear as rounded masses, rolls, etc., with breaks of clear sky in between.

Nimbostratus cloud

Cirrus: It's Latin for "curl." Cirrus clouds look like curls of white hair. The most common form of high-level clouds are thin and often wispy cirrus clouds. Typically found at heights greater than 20,000 feet (6,000 meters), cirrus clouds are composed of ice crystals that originate from the freezing of supercooled water droplets. Cirrus generally occur in fair

Cloud Classifications

Meteorologists name clouds by how high in the sky they form and by their appearance. Most clouds have two parts to their name. Usually the first part of the name has to do with the height and the second part refers to the appearance.

If clouds form at the highest levels, they get the prefix “cirro” as the first part of their name. Middle clouds get the prefix “alto.” Low clouds don’t get a prefix.

There are two cloud appearance types: cumulus and stratus, which are also the basic names of the low clouds. Sometimes they appear higher in the atmosphere and get a combination name with a prefix. For example, middle cumulus clouds are called “altocumulus” and high stratus clouds are “cirrostratus.” If a cloud produces rain or snow it gets either “nimbo” at the beginning or “nimbus” at the end.

Cumulus clouds are individual, billowy globs that are low, have flat bases, and look a little like cauliflower. They are at least as tall as they are wide and form on sunny days from pockets of rising air. Their constantly-changing outlines are fun to watch because they can take the shapes of almost anything, including animals and faces. Cumulus clouds usually signal fair weather. If they build into the middle or high part of the atmosphere, they get the name cumulonimbus. A cumulonimbus cloud is tall, deep and dark and can bring lightning, heavy rain, and even severe weather such as hail, damaging winds or tornadoes. It is a sign of rapidly rising and sinking air currents.

Stratus clouds are layered and cover most of the sky. They are much wider than they are tall. If you see them in broken or puffy layers, they are stratocumulus clouds. If you see them in thin high layers that turn the sky solid white, they're cirrostratus clouds. The tiny prisms of ice in a cirrostratus layer can bend weather and point in the direction of air movement at their elevation. These clouds often predict rain within the next day or two.

Cirrus Cloud

the sun's light. As a result, often you can see a halo or veil of rainbow colors around the sun. When stratus clouds are very thick, they become dark nimbostratus clouds, which can produce rain, drizzle or snow.

Cirrus clouds are high and thin and made entirely of ice crystals. Forming above 20,000 feet in the atmosphere, they often look like wisps of white hair. Cirrus clouds, which are a sign of warm moist air rising up over cold air, are sometimes an early signal that thickening clouds could bring light rain or snow within one or two days.

Try to learn the names of the different clouds, and the next time you look up into the sky, take notice of what kind of clouds you see. And if you try, you might be able to guess what kind of weather they will bring.

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Exercise
1 – 4

STUDYING THE WATER CYCLE

Objective:

Students will learn about the water cycle through simple experiments and hands-on activities.

Materials:

- Rain barrels. Pickle barrels are often available from distributors, though plastic garbage cans can also serve.
- Rulers
- Journals
- A good poster of cloud types
- Outdoor thermometer

Procedure

Students should use their note books to record whether conditions through out the season. Temperature, rainfall and season will start to reveal patterns that allow gardeners to become weather forecasters.

1. Ask the students to list the many ways the plants and animals at their various sites obtain water both naturally and by human intervention.

2. Ask students to think about the form that water assumes in different seasons. For example, observe the effect melting snow may have on the soil and how this will affect plants and trees in spring.

3. Discuss the necessity of working with nature to optimize the success of the spring planting by timing it to maximize the spring rains.

4. Observe the weather patterns, sketch and identify clouds that will bring rain. Learn to know when rain will likely settle in or when it will just be a passing shower based on times of day they occur and seasonal patterns.

5. Where does this rainwater go after it falls?

6. Set up rain barrels wherever possible connecting them to gutters and down spouts if possible. Using a rulers measure the rainfall and note it down. Use rainwater to water plants.

7. Discuss the journey of a raindrop through the cycle by pointing out which stage of the cycle water is in at any given time.

8. In their eco-journals, have student draw and write about the hydrologic cycle.

Lesson
1 - 4

Exercise 4

SKILLS

Basic arithmetic skills

Journal writing

Measuring

Observe cloud patterns

Understanding season weather patterns

VOCABULARY

Catchments

Cycle

Hydrologic

Extended Activity

Observe appropriate rain harvesting potential at all active sites. Where no potential exists, explore ways of creating catchment by using existing features such as shelters, sheds, and shade buildings or erecting simple structures.

More Activities

1. Discuss conservation of water in the home.
2. Place a 1/2 gallon jar in the water holding tank of the toilet to save 10% of the water with each flush.
3. Have the students learn how to fix leaks and check the faucets in their homes.
4. Encourage the students to shut the water off while brushing their teeth.

Water Pollution

For years, people have used Earth’s waterways as the dumping ground for various materials. People thought the effects would be minimal because pollutants were dispersed over oceans, rivers, and lakes. Now we know that water pollution can have serious and long-lasting effects even in vast areas of water.

Pollution of our waterways is caused by a variety of substances. Radioactive materials from uranium and thorium mining, rubbish, organic chemicals, infectious materials, fertilizers, and plant nutrients, sediments of soil and minerals particles eroded by storms and floodwaters, sewage and other oxygen-depleting waste have all found their way into our waterways.

Eutrophication, which is the abnormal growth of aquatic plants, occurs when synthetic nutrients leak into lakes. These artificial nutrients generate abnormal growth of aquatic vegetation. In return, these plants in return deplete the oxygen supply in the lake as they decay. Bad-tasting water, foul odors, and ugly green scums of algae are some of the products of eutrophication.

The urgent need to control these impurities led to the approval of the 1972 Federal Water Pollution Control Act. Strict controls and cleanup deadlines were established for industrial and municipal pollution. Supplemental provisions to this law helped to strengthen the suppression of toxic water pollution.

Exercise
1 – 5

STUDYING HOW PLANTS ABSORB POLLUTANTS

Objective:

To show the students to how plants will absorb pollutants from water.

Materials:

- Jars
- White cut flowers or sticks of celery
- Food coloring

Procedure

1. Review how plants use water.

2. Share the materials you have gathered with the students and allow time for discussion of what they might be used for.

3. Explain that the students will be doing an experiment to show how plants can absorb pollutants from the water.

4. Place some food coloring in the jars and then add water. Trim the stems of the plants and stand them in the colored water for several hours.

5. Ask students to form a hypothesis about what will happen to the plants over time.

5. Let the students observe the discoloration of the plants by the absorption of the “pollutant” in the water.

6. Return and measure rate of absorption.

Lesson
1 - 5

Exercise 1

SKILLS

Forming a hypothesis

Observation

Recording results

Staging a simple experiment

VOCABULARY

Absorption

Discoloration

Hypothesis

Pollutants

Students' Annotated Bibliography

Hunken, Jorie. *Ecology for all ages : discovering nature through activities for children and adults* / by Jorie Hunken. 1st ed., Old Saybrook Conn.: Globe Pequot Press

Swain, Roger B. , *Groundwork : a gardener's ecology* / Roger B. Swain ; illustrated by Abigail Rorer. , Boston : Houghton Mifflin, 1994

Grissell, Eric. *Insects and gardens : in pursuit of a garden ecology* / Eric Grissell ; with photographs by Carll Goodpasture., Portland Or. : Timber Press

New York City Urban Park Rangers. *From lean to green : a guide to the rehabilitation of inner city forests* / [New York City Urban Park Rangers]. , [New York] : Enterprise Press, 1996

Lady Muck. *Magic muck : the complete guide to compost* / Lady Muck ; illustrated by Tim Coath. , London : Pavilion , 1994

Teacher's Annotated Bibliography

Taylor, Jane, 1944-, *Weather in the garden* / Jane Taylor., Sagaponack N.Y. : Sagapress , 1996

Chapter 2: Understanding Plants

Performance Objectives

Students will be able to:

- Identify the structure of a plant.
- Describe the function of each part of a plant listed in the vocabulary.
- Define various classes of plants listed in the vocabulary.
- Perform a dissection of a plant.
- Explain the sexual reproduction of a plant.
- Cite examples of each different class of plant listed in the vocabulary.
- Describe the process of photosynthesis.
- Demonstrate the effects of water on a plant.

Assessment will be based on several criteria:

- The student must complete all exercises according to direction.
- The student must complete all written reports.
- The student will perform all measurements accurately.
- Each member of the group will be evaluated individually. A group evaluation will also be given.
- All descriptions must be clearly written.

Lesson
2 - 1

SKILLS

Knowledge of the structure of plants

Knowledge of the relationship of plants to all life on earth

Knowledge of the sexual reproduction of plants

Knowledge of the function of each principal part of a plant

VOCABULARY

Herbaceous
Woody
Annual
Perennial
Biennial
Simple
Compound
Alternate
Opposite
Whorled
Fibrous
Advantitious
Taproot
Rhizome
Bulb
Tuber
Xylem
Phloem
Node
Internode
Fertilization
Monocot
Dicot
Cotyledon

Understanding Plants

There are hundreds of thousands of known species of plants from a diverse and complex group of organisms that can be as simple and small as microscopic algae or as large as a 300-foot-tall redwood. Plants are the oldest living things on earth; there are plants living today that are thousands of years old. We cannot duplicate the chemical processes of plants—most notably photosynthesis. Plants contain within their structures thousands of useful compounds. Many of these compounds provide the ingredients of important medicines, polymers, resins, fragrances, spices, and products that are both desirable and necessary to humans.

Most plants share a similar anatomy. An annual of a year's duration has all the same basic parts as a giant sequoia.

Plant Structure

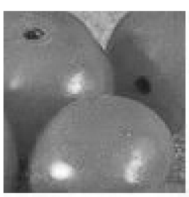
Plants can be either herbaceous or woody. Most herbaceous plants have stems that are soft, green, and contain little woody tissue. These plants are ones that die to the ground each year. Most annual and perennial flowers fall into this category along with vegetables and houseplants. Woody plants have tough structures that remain in place all year.

Herbaceous plant

Woody Plant

Life Cycle

A plant's life cycle describes how long a plant lives or how long it takes to grow, flower, and set seed. Plants can be either an annual, perennial, or biennial.



Annual
A plant that completes its life cycle in one growing season. It will grow, flower, set seed, and die. Most food crops are annual with the exception of fruit trees and vines and a few perennials like asparagus.
Examples: marigolds, tomatoes, and petunias.

Perennial
A plant that lives for 3 or more years. It can grow, flower, and set seed for many years. Underground parts may re-grow new stems (as in the case of herbaceous plants), or the stems may live for many years like woody plants (trees). Many perennials will flower only once per year. Their strategy for survival is to concentrate on making strong roots that can endure seasonal changes.
Examples: daisies, chrysanthemums, and roses.

Biennial
A plant that needs two growing seasons to complete its life cycle. It grows vegetatively (produces leaves) one season. Then it goes dormant or rests over the winter. In the spring, it will begin to grow again and grow flowers, set seed, and die. The seed that is left behind on the ground germinates and the cycle begins again.
Examples: parsley, carrots, and foxglove.

Plant Parts

Basic parts of most all plants are roots, stems, leaves, flowers, fruits, and seeds.

Simple

Compound

Leaves

Leaves are the food-making factories of green plants. Leaves are made to catch light and have openings to allow water and air to come and go. The outer surface of the leaf has a waxy coating called a cuticle that protects the leaf. Veins carry water and nutrients within the leaf. Leaves are the site of the food making process called photosynthesis. In this process, carbon dioxide and water in the presence of chlorophyll (the green pigment) and light energy are changed into glucose (a sugar). This energy-rich sugar is the source of food used by most plants. Photosynthesis is unique to green plants! Photosynthesis supplies food for the plant and oxygen for other forms of life. A green plant helped make the oxygen you are breathing today.

Leaves come in many different shapes and sizes. Leaves can be simple. They are made of a single leaf blade connected by a petiole to the stem. An oak leaf or a maple leaf are examples. A compound leaf is a leaf made up of separate leaflets attached by a petiole to the stem, like an ash or a locust.

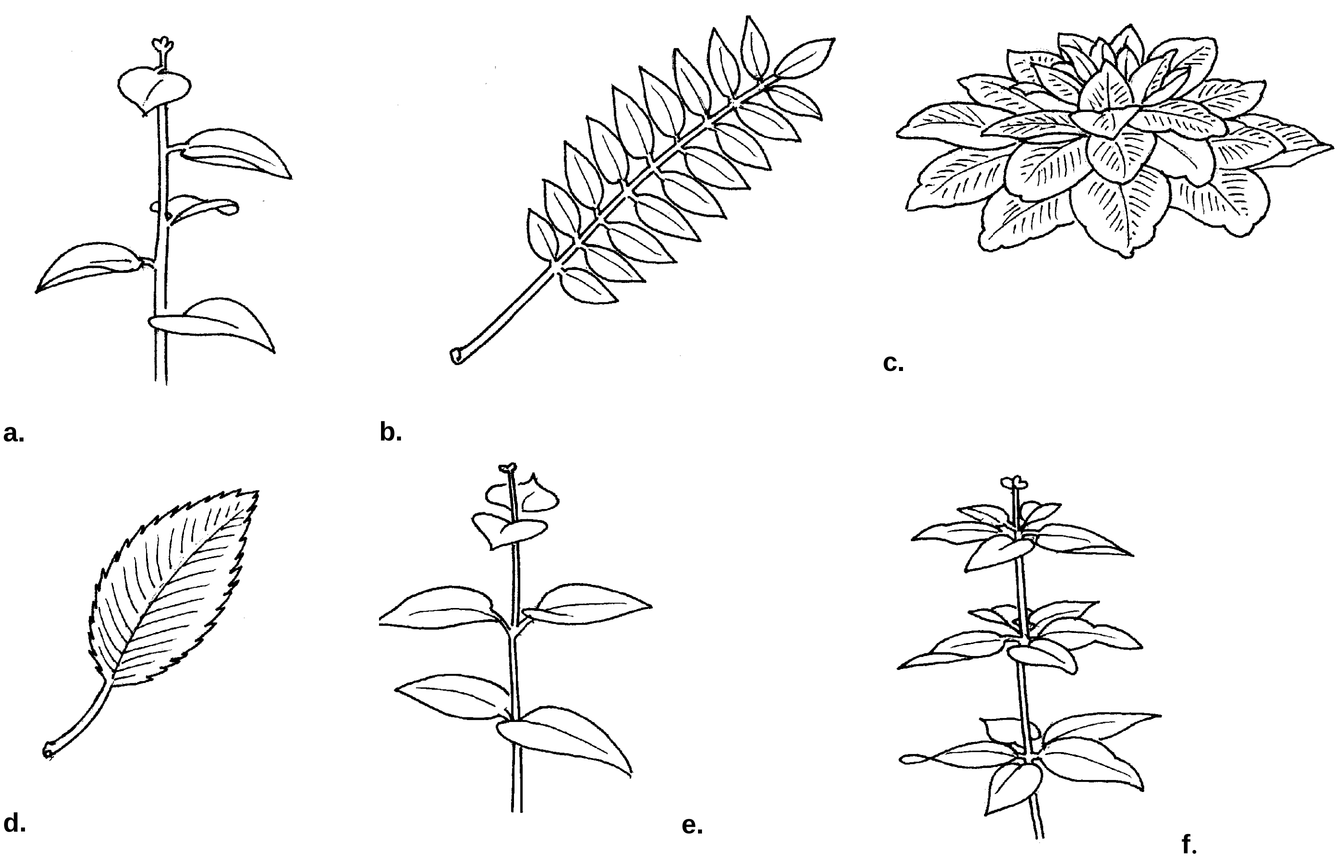


Fig. 5. Leaf Types. a. Alternate (bush bean); b. Compound (ash); c. Roseate (lettuce); d. Simple (birch); e. Opposite (mint); f. Whorled (bedstraw).

Roots

The roots help provide support by anchoring the plant and absorbing water and nutrients needed for growth. They can also store sugars and carbohydrates that the plant uses to carry out other functions. Plants can have either a taproot system (such as carrots) or a fibrous root system (such as turf grass). In both cases, the roots are what carry the water and nutrients needed for plants to grow.

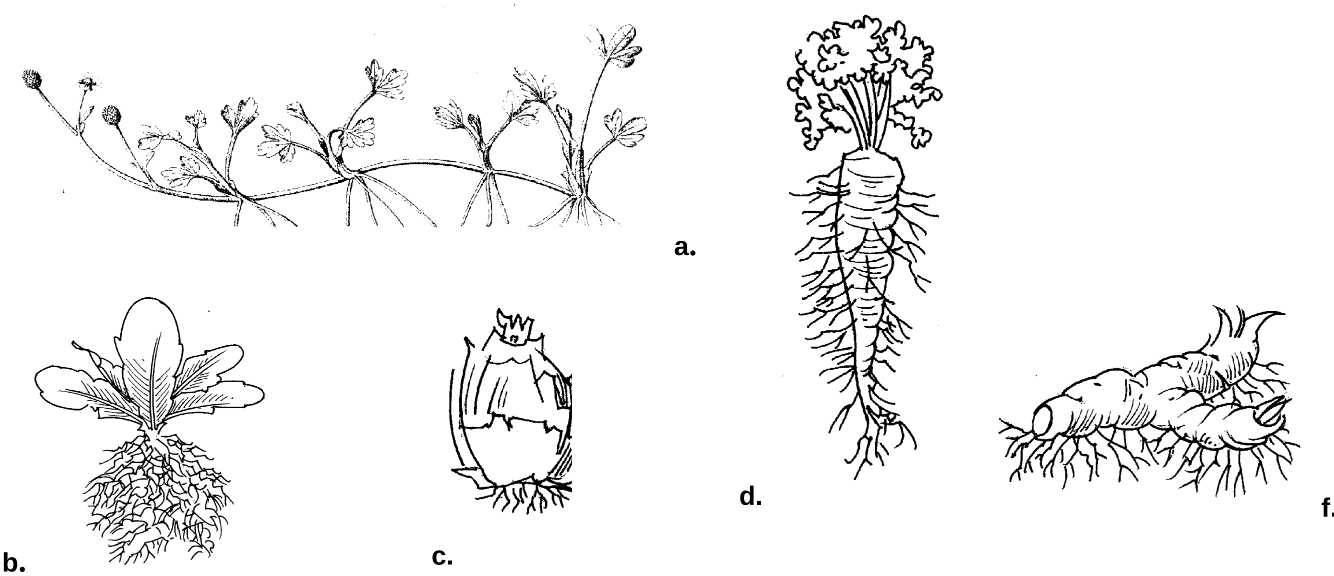
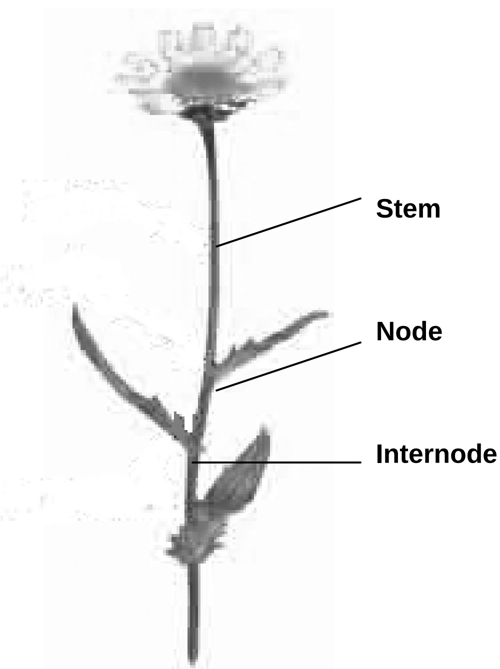


Fig. 1. a. Adventitious (strawberry); b. Fibrous (kale); c. Bulb (narcissus); d. Taproot (carrot); e. Rhizome (iris).



Stems

Stems carry water and nutrients taken up by the roots to the leaves. Then, the food produced by the leaves moves to other parts of the plant. The cells that do this work are called the xylem cells. They move water. The phloem cells move the food. Stems also provide support for the plant, allowing the leaves to reach the sunlight that they need to produce food. Where the leaves join the stem is called the node. The space between the leaves and the stem is called the internode.

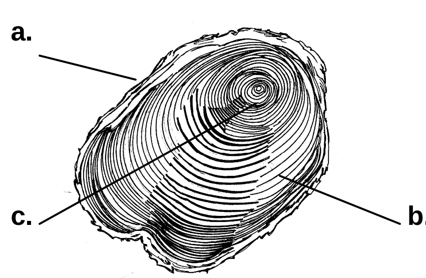


Fig. 2. Tree rings. a. Bark; b. Rapid growth; c. Slow growth.

Flowers

Flowers not only look pretty but also in fact are important in making seeds. Flowers have some basic parts. The female part is the pistil. The pistil usually is located in the center of the flower and is made up of three parts: the stigma, style, and ovary. The stigma is the sticky knob at the top of the pistil. It is attached to the long, tube-like structure called the style. The style leads to the ovary that contains the female egg cells called ovules.

The male parts are called stamens and usually surround the pistil. The stamen is made up of two parts: the anther and filament. The anther produces pollen (male reproductive cells). The filament holds the anther up.

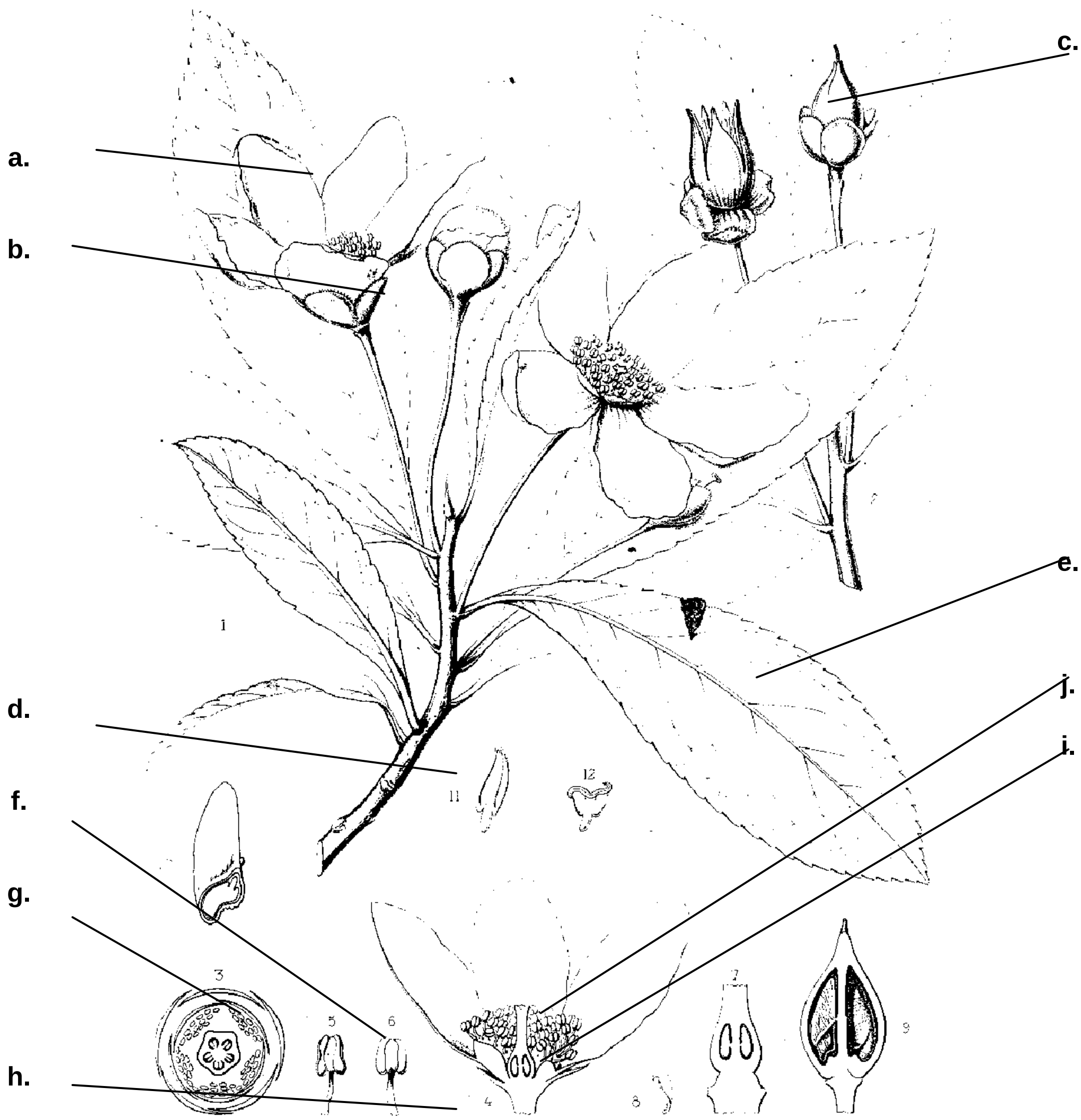


Fig. 7. a. Petal; Sepal; c. Bud; d. Stem; E. leaf; f. Ovule (cross section); g. Anther; h. Stamen; i. Ovary; j. Style

During the process of fertilization, pollen lands on the stigma, causing a tube to grow down the style and enter the ovary. Male reproductive cells travel down the tube and join with the ovule, fertilizing it. The fertilized ovule becomes the seed, and the ovary becomes the fruit.

Petals are also important parts of the flower because they help attract pollinators such as bees, butterflies, and bats. You can also see tiny green leaf-like parts called sepals at the base of the flower. They help protect the developing bud.

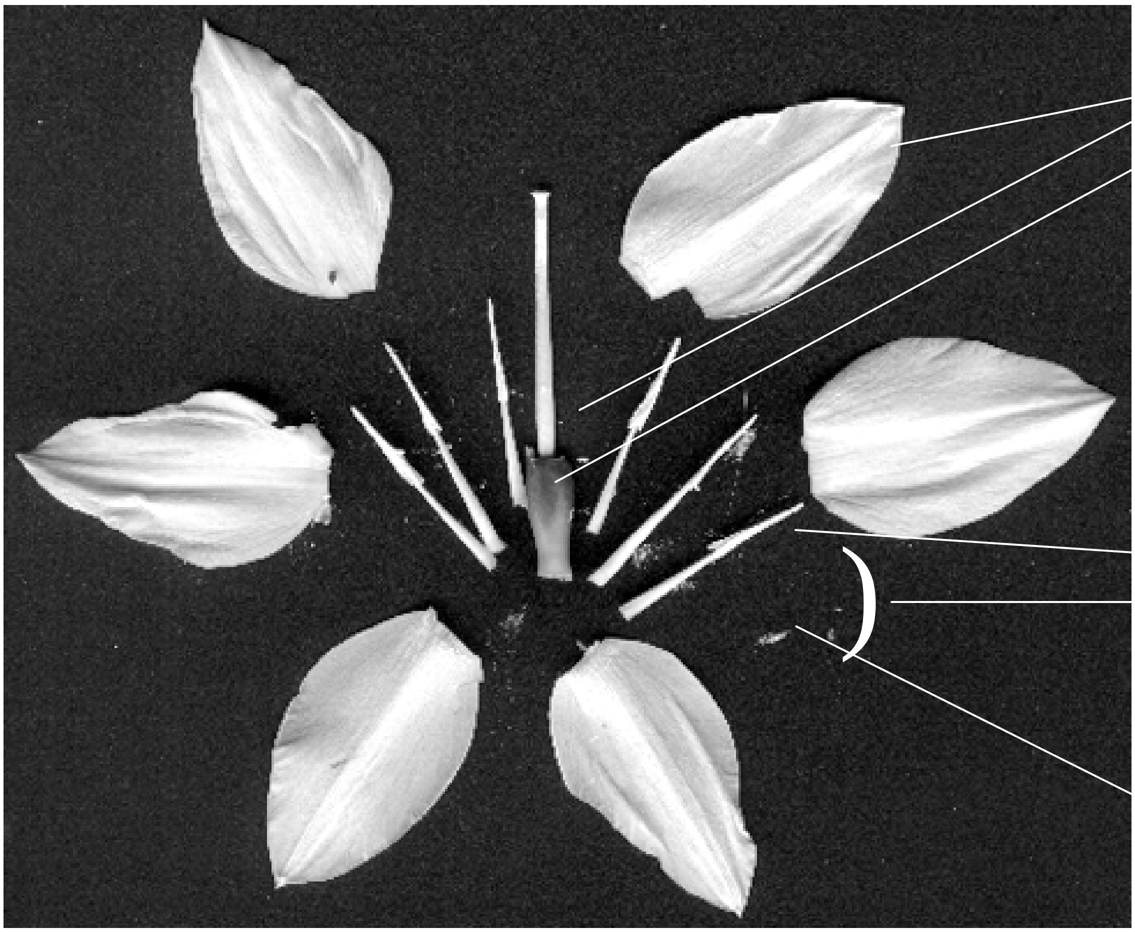


Fig 8. The parts of the flower have been carefully dissected and laid out on a dark background so that they can be easily seen and studied.

Fruit

The fruit is the ripened ovary of a plant containing the seeds. After fertilization, the ovary swells and becomes either fleshy or hard and dry to protect the developing seeds. Many fruits help seeds spread (such as maple seeds). Many things we call vegetables are really fruits such as tomatoes, cucumbers, and beans.

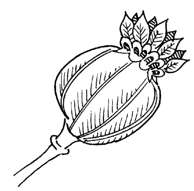
These are all ripened ovaries and are really fruits—the products of fertilization.

Seeds

Seeds are a plant's way of getting from one area to another by wind, water, or animals. Every seed is a tiny plant (embryo) with leaves, stems, and root parts waiting for the right things to happen to make it germinate and grow. Seeds are protected by a coat. This coat can be thin or thick and hard. Thin coats don't protect the embryo well, and thick coats help the embryo survive tough conditions.

The seed also contains a short-term food supply called the endosperm, which is formed at fertilization but is not part of the embryo. It is used by the embryo to help its growth. In the bean that is shown, the endosperm is no longer there. It has been used for the growth of the embryo, and most of its nutrients and energy are now in a different form within the tissues of the cotyledon or non-photosynthesizing seed leaf. Plants with one cotyledon (like corn) are called monocots. If they have two cotyledons (like beans), they are called dicots.

a.



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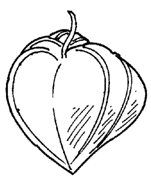

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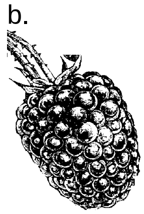

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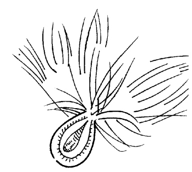

r.

Fig. 8. Seeds which are contained within a fruit: a. Plum; b. Poppy; c. Apple; d. Husk Tomato; e. Blackberry; f. Dandelion

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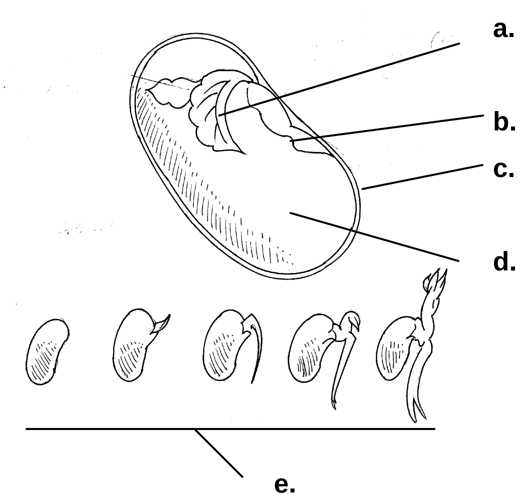


Fig. 9. Parts of the bean plant: a. First leaf; b. Radicle (embryonic root); c. Seed coat; d. Cotyledon; e. Stages of germination.

Exercise 2 - 1

PLANT ANATOMY

Objectives:

To understand that the flower contains the sexual organs of the plant and to learn its parts through research and dissection of a flower

Materials:

1. Fresh flowers (gladiolas or tulips)
2. Magnifying glasses, paper towels, scissors, glue, card stock
3. Botany or Biology book

Procedure:

1. Spread paper towels on the desks and pass out the previously collected fresh flowers. Each student will have one flower.

2. As a class, identify and cut out the various parts of the flower. It is important not to destroy the parts because they will be used to create the diagram.

3. Now, use the actual flower parts to make a diagram. Students will glue the parts of the flower to the card stock, label the parts, and write a short explanation of the flower part diagram to describe each part's function.

Later: Students will look for parts in different flowers around their garden or in pictures. Since not every flower is the same and they do not all have easily identifiable parts, look for other flowers or pictures of flowers.

Lesson 2 - 1

Exercise 1

SKILLS

Dissection

Identification of the parts of a plant

Diagramming

Understanding of sexual reproduction in plants

VOCABULARY

Petals

Pistil

Stigma

Style

Ovary

Ovule

Nectar guides

Stamen

Sepals

Stem

Leaves

Roots

Anther

The Use of the Scientific Process (Hachten, 1996)

Our curriculum is not only designed to teach the practical skills of gardening, but also to educate students in the scientific processes that underlie every aspect of the natural world. By focusing on the scientific method, students will learn to discern these processes for themselves through observation and description. Students will engage in hands-on activities and experiments that require forming a hypothesis, testing that hypothesis, and reaching conclusions. Gardens will be the laboratories where they generate questions and achieve answers.

New Life in the Garden

Twice monthly, HSNY Interns meet at our office for a creative writing class. Today, students are assigned to answer several questions from quizzes on the back pages of magazines. The answers are meant to be casual: our likes and dislikes; the things that make us proud and the things that we are not especially proud of. When it comes time to read out the answers, Lorenzo tells us that the thing that he likes is gardening. The thing that he is proud of is how good it makes the neighborhood look. The thing that he does not like is when people act as if they don't care. He says that the nice thing about the garden is that one can never really grow tired of being with the plants. Other students chime in about the discoveries that they have made in the garden—how things fit together to make a world that they never dreamed existed. Another student is honest. He says that before he started the HSNY program, he did not know and did not want to know. Wilkins B. is not a seasoned criminal by anyone's standards, but he was well on his way to becoming just another statistic—a young black male, a high school dropout, and unemployed.

When he was arrested five months ago for drug possession, he was worried about being sent to jail. "The judge said this was my last chance. If I didn't do a training program, I would be going to jail for 6 months," he recalls.

An intelligent, charismatic young father of two, Wilkins had reached a dead end in his life. Frustrated and angry with himself, at first he wasn't ready to listen when a social worker proposed that he enroll in a job-training program. "I told her, 'I'm not going to talk to anyone in the program, just like I'm not I'm not talking to anyone in here.'"

As a social worker, I see many clients who have defensive attitudes like Wilkins. I've learned that it is a coping mechanism used to protect themselves from a system that has not yet earned their trust. Wilkins needed to feel like he could trust us, and we needed to be trustworthy.

Wilkins was sent to F.E.G.S Career Development Institute (CDI) for the remainder of his mandate. They offer a variety of job training and employment programs that provide skills to young adults ages 19 to 21. They empower young adults like Wilkins to learn new skills, earn valuable educational and professional credentials, and land a job in a career of their choice.

Wilkins, however, did not have a preference. He heard about HSNY and decided to give it a try. "I spent the first two days observing," Wilkins recalls. "I wasn't sure what to expect, but then I saw that these people were really trying to help me. They just kept killing me with kindness. Before I knew it, my mandate was over." Wilkins decided to stay at

F.E.G.S/CDI, and soon afterwards he was placed in the HSNY horticulture program they provide, a paid internship that last a couple of months. Wilkins loves it: “I’m so happy to be doing something different, now when I’m on my block, talking to my friends, I talk about something positive. While they’re talking about the new 2005 Lexus, I’m talking about London planes and oak trees.” He says that it’s like giving a little help back to nature, since she gives so much to us in return. “I was a little resistant at first; I wanted to make sure HSNY was serious about helping me. If I’m going to give my time, I want to see your dedication. And I’ve seen more dedication than I could expect—it’s still going on and my case was over months ago.”

Wilkins’s journey has just begun and with help he will continue to improve his situation. He’s glad that he’s no longer on the same destructive path, and he wants to make sure he doesn’t go back. “On my bedroom mirror I have the court papers to remind me, ‘Dude—don’t do it!’ I want to be an example for others about turning a negative into a positive.”

It is unrealistic to assume that everyone who comes through HSNY will have the same results as Wilkins, but it is important to give everyone who is sent to us that opportunity. At HSNY, success is measured by the small steps individuals make towards positive change. In the broadest sense, life is at the center of our curriculum.

Photosynthesis

Photosynthesis, the process by which plants produce their own food, is at the center of the creation and continuation of life on the planet. The process of photosynthesis is essential for the growth of most plants on land and in the oceans of the world. This unit will explore this life-giving process through student observation, description, and explanation. By using the scientific method, students will also connect photosynthesis to other scientific fields. They will engage in writing, reading, and mathematics as they explore photosynthesis in this unit. Students will also consider photosynthesis when they plan, design, set up, maintain, and evaluate their urban gardens.

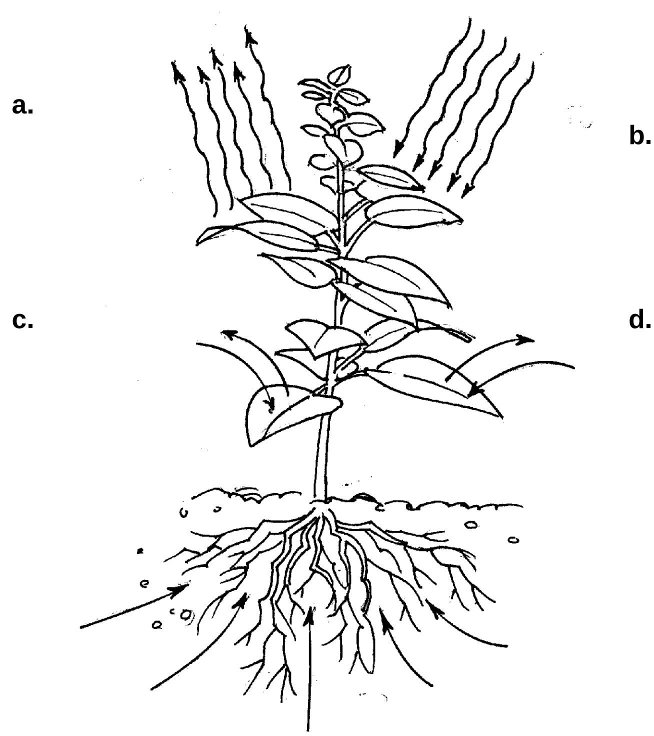


Fig. 10. Photosynthesis and plant growth
a. Transpiration (water release)
b. Sunlight absorption
c/d. Oxygen and carbon dioxide (CO_2) exchange
e. Nutrient and water (H_2O) absorption

Exercise
2 - 2

THE ESSENTIAL ELEMENTS OF PHOTOSYNTHESIS

This exercise is designed to teach students about the elements required for photosynthesis using the scientific method.

In the training, "The Chemistry of Photosynthesis" is essential because it sheds new light on work in the field.

Materials: (per pupil)

- Empty box
- 1 cup of soil
- 1 cup of water

Procedure:

1. Place a carefully measured cup of soil and an equally measured cup of water into the box.

2. Cover the box and ask the students identify the elements of life necessary for plant growth.

3. Tell them there are four elements necessary to plant life, and thus to all life. The box contains two of them. Which are the missing elements? Compare them to the ingredients in a recipe if that is easier for the students to assimilate. If we cover the box, we eliminate one of the ingredients. What is this ingredient?

4. Students could challenge each other in trying to name the essential elements. One of them will realize that light is one of the elements necessary for a plant to grow. By covering the box, we cover the source of light.

5. Then, ask them about the fourth element necessary for the process of photosynthesis. Without the instructor telling them directly, they will sooner or later realize that the element not accounted for is carbon dioxide present in air.

This method of asking questions and arriving at answers through observation marks the beginning of the scientific process.

Lesson
2 - 2

Exercise 2

SKILLS

Deductive reasoning

Understanding of the fundamental elements of photosynthesis

Working as a member of a group

VOCABULARY

Photosynthesis

Essential

Elements

Blending Work and Observation in the Field

By March, students are already working in the field, making it difficult to find time to devote to more abstract elements of the curriculum. Use lunch breaks for discussion, and save experiments for the times when there is less work in the field or for a time when the exercise can be folded in seamlessly into work in the garden. For example, when sowing, do Exercise 2-2. Midsummer is a time of routine maintenance. The pressures of planting are done and the natural rhythms of gardening allow for reflection. Now we can begin to analyze the process of photosynthesis. Bring out the notebooks again and look back at what was recorded at the time of sowing. How have the four elements combined to produce the garden students see now? The key lies in the composition of air, in water, and in the energy of the sun.

All around in the garden we can see the results of our good care. The garden is full of plants in every stage of development from the tiny seed still present in the mother plant to those that have already dropped to the earth. Others have already germinated and still others are on their way to adulthood. A plant in growth allows us to visualize the process of the production of sugar by examining its leaves.

A brief background of the history of the discovery of the process of photosynthesis would be appropriate at this point (Conant, 1957). Its history is fascinating since it has not been long since the process has been scientifically explained. In fact, it was not until the beginning of the Nineteenth Century that De Suassure came up with a fairly clear picture of the dynamics of photosynthetic materials (Conant, 1957: 420). The concept of “gas” itself only became part of the common parlance of the scientific community in the beginning of the Seventeenth Century through the experiments of the Belgian physician Baptista van Helmont (Conant, 1957: 327-328). Tell the discovery of photosynthesis as a story, a mystery solved by scientific detectives. Emphasize that students can also make discoveries in the natural world using the same processes of observation and deduction. Now they are ready to discuss the process, including more detailed accounts of its components. Students should be able to put the process in perspective and be able to visualize it clearly.

Most people have heard of photosynthesis, though it is very common to encounter students that have not yet heard of it or only have a vague or confused idea of what it means and very often feel nothing for the process at all, regarding it as an esoteric thing of no real importance to their lives. It is even very common for “well-educated” people to have no clear idea of the process’s true workings.

Below is the equation which signifies the mechanics of the chemical process. There have been students that could actually name out the constituent parts of this formula yet did have much connection with the process. Other students already felt an emotional relationship with the sun that transcended the kind of literacy that would allow them to decode the equation below. Each must learn from the other. The chemical coefficients alone do not represent understanding of photosynthesis. Understanding can only come through direct experience of the process through close observation and consideration of what we know about the life of plants.

CO_2 + H_2O + ENERGY FROM THE SUN AND CHLOROPASTS = SUGAR + O_2

In other words, the photosynthetic apparatus in the chloroplast makes the following chemical reaction occur:

$6CO_2 + 6H_2O + \text{LIGHT ENERGY} = C_6H_{12}O_6 + 6O_2$

Later on, as students' understanding and enthusiasm increases, we could discuss the more complex relations of photosynthesis and respiration and some of the details of oxidation and reduction (Walker, 1993: 13, 16-17). At this stage of the game, it would be enough to talk about the fact that a chemical equation operates as a kind of recipe which, when one knows how to read it, expresses the balance fundamental to nature. Matter can neither be destroyed nor created. We start with 6 carbons, 18 atoms of oxygen, and 12 of hydrogen and we end up with the same amount on the other side of the equation, expressed in the production of the sugar molecule, $C_6H_{12}O_6$, and the oxygen bond, O_2. The use of manipulatives to present the formation of molecules to the class can also contribute to the understanding of the process of sugar production by plants. This will also explain the law of conservation of matter.

Discovery of Photosynthesis

In 1648, the Flemish plant physiologist Johannes Baptista van Helmont planted a 5-pound willow in 200 pounds of soil. After five years, he removed the willow and found that it weighed 169 pounds 3 ounces. Reweighing the soil after it had dried, he found that it now weighed 199 pounds, 14 ounces. In other words, 164 pounds 3 ounces of willow was produced by only 2 ounces of soil.

How could this be did the plants create this growth from thin air? These kinds of questions open up the student to the possibility of cognitive development through experiential learning. Nature is a wonderful classroom where students can touch, smell and taste learning. At first students may be puzzled at why we care to know the answer to these questions. It is common for people that lack understanding of the complexity of life to believe that they already know what they need to know or can easily learn it. But as experience begins to take the place of false self-confidence students may complain that they now understand absolutely nothing of what we are doing. A student has said to me "At least I used to think that sometimes there were some things that I understood but now I do not understand anything." This is the beginning of true understanding. When we understand nothing it is the same as feeling that we understand everything or at least that we are able to understand everything. Now that the student begins to understand through experience they are exposed first hand to the mysteries of how the world is organized in ever more complex digressions from the sun which is millions of light years away that powers the chemical processes that make life on earth possible to all the creatures from man on down the microscopic life that partake and participate in the process. The "taste" of this experiential understanding was unknown to the student before. And now the taste of understanding seems to be lack of understanding.

In our talks we often returned to the impressions our friends had of us and the impressions that we now have of our former lives. We begin to realize that these new ways of learning can either unite people or separate them. Such submission as not knowing or understanding life is the most difficult thing that there can be for a person who thinks that they are capable of deciding everything and doing everything. Gradually when the student gets rid of these fantasies and sees what they really are, the difficulty in learning should lessen. This can only take place in the course of work which will require an effort. But to begin the work of learning how to learn and to continue it is very difficult and it is difficult because our life is too easy and we have lost the connection between the food that we eat and an understanding bore of experience of the complex processes – like photosynthesis -- that make that food a possibility.

Exercise
2 - 3

PROVING THE EFFECTS OF WATER ON THE DEVELOPMENT OF PLANTS

Objective:

To illustrate the production of sugar by plants (as evidenced by leaf and flower size) and its relation to watering. This exercise is best done during the time of seed germination in an indoor setting with controlled conditions.

Materials:

- 9 small pots
- Uniform potting soil
- 9 bean seeds
- Graph paper
- Notebooks

Procedure:

1. Set out nine small pots with uniform amounts of soil (pots produced from recycled material are best).

2. Plant a seed in each of the pots.

3. Separate them in sets of three.

4. Give each set a different amount of water.

5. Make sure that other conditions are similar, including light and temperature.

6. Formulate a hypothesis: The seeds with more water are going to grow larger than the others.

7. Students should record information, making a graph with baseline of time and a vertical axis of growth. Record growth in each of several ways on several charts: overall height, leaf size, number of leaves for each group of plants.

8. Take daily measurements.

9. Continue these measurements for 4 – 6 weeks

10. Ask students which group has the largest leaves and flowers. Based on their answers to this question, invite them to draw conclusions about which plants have the most food. Does this correlate to the amount of water they have received?

Lesson
2 - 3

Exercise 3

SKILLS

Tracking

Understanding of the effects of water on a plant's development

Measuring results

VOCABULARY

Hypothesis

Conclusion

Analysis

Oxidation

Reduction

Chemical equation

Scientific process

Exercise
2 - 4

PHOTOSYNTHESIS: ELODIA EXPERIMENT

Chlorophyll uses light energy to perform photosynthesis; the chlorophyll is required to power several reactions in order for this to happen. If there is an increase in light, these reactions will take place faster and will produce more glucose and oxygen. This will only happen for a certain amount of time.

Objectives:

The student will:

- Observe evidence of photosynthesis in a water plant.
- Assemble the equipment needed to measure the rate of photosynthesis in elodea (water plant).
- Count bubbles of oxygen gas given off by elodea to determine the rate of photosynthesis.
- Change the conditions of photosynthesis by altering light intensity and carbon dioxide amount, and determine the effects on the photosynthesis rate.
- Prepare a graph of the collected data and analyze it.

Materials: (For each group of four students)

- Elodea (water plant available in pet stores)
- Lamp (40 watt)
- Test tube
- Razor blade (single-edge)
- Dechlorinated water (room temperature)
- Tape
- Sodium bicarbonate powder (baking soda)
- Clock or timer
- Metal stand with rod or test tube rack
- Metric ruler

Procedure:

PART A. Setting Up the Experiment

1. Obtain a sprig of elodea. Remove several leaves from around the cut end of the stem. Slice off a portion of the stem at an angle and lightly crush the cut end of the stem.
2. Place the plant into a test tube filled with water, stem end up.
3. Secure the test tube to a metal stand with tape or place the test tube in a test tube rack.

PART B. Running the Experiment

1. Place a 40 watt lamp 5 cm from the plant. After one minute, count and record the number of oxygen bubbles rising from the cut end of the stem. Count bubbles for five minutes. If bubbles fail to appear, cut off more of the stem and re-crush.
2. Run a second five-minute trial. Record and average your results.
3. Move the lamp so it is 20 cm from the plant. After one minute, count and record bubbles for two five-minutes trials. Again, average and record your results.
4. Add a pinch of sodium bicarbonate powder to the test tube. Place the lamp 5 cm from the test tube. After one minute, record bubbles for two five-minute trials. Average and record your results.
5. Prepare a graph of your results. Use the average number of bubbles for the vertical axis. Use the type of environmental condition for the horizontal axis.

Exercise
2 - 5

PHOTOSYNTHESIS: ELODIA EXPERIMENT

Performance Assessment:

The students will answer these questions using specific values from the investigation. Diagrams may be included.

1. How does this investigation demonstrate that plants give off oxygen during photosynthesis? Explain your answer based on your observations.

2. How does the rate of photosynthesis change when the light source is moved from a distance of 5 cm to 20 cm?

3. How does the rate of photosynthesis change when sodium bicarbonate is added to the water?

Conclusions:

Plants use green pigments called chlorophylls to trap light energy. The chlorophylls give a plant its green color. Inside the cells that have chloroplasts, the light energy is used to make a simple sugar called glucose. The process by which plants use light energy to make glucose is called photosynthesis.

During this process of sugar production, carbon dioxide combines with water to form glucose and oxygen is released. Oxygen that is produced in photosynthesis is given off as a gas. If a lot of oxygen is being given off, photosynthesis is occurring rapidly. If little oxygen is being given off, photosynthesis is occurring slowly. The amount of trapped light energy and the amount of carbon dioxide available affects the rate of photosynthesis.

The purpose of adding sodium bicarbonate is to increases the amount of carbon dioxide in the water.

This investigation can be performed with water plants grown in many parts of the world (except regions that have permanent ice).

Lesson
2 - 5

Exercise 5

VOCABULARY

$C_6H_{12}O6$ (the chemical composition of sugar).

Chlorophyll

Chloroplast

CO_2 (carbon dioxide)

Conservation

Diversity

Energy

Flora

Glucose

H_2O (water)

High energy compound

Low energy compound

MgN_4 (chlorophyll)

Photosynthesis

Process

O_2 (oxygen molecule)

Oxidation

Reduction

Scientific process

Urban garden

Water splitting

Benefits of Learning the Scientific Method

Students will constantly engage in on-going garden projects with at many different sites. There will be many opportunities to train themselves as observers. To be a gardener one must learn to observe by asking questions and making predictions. Would a plant grow faster with tap water or with water from rain harvesting? Beginning with simple questions is a good way to encourage students to have fun and make their observations more acute. Students' work in the field will begin to link with their understanding of the scientific aspects of plant growth. A deeper understanding of photosynthesis will bring new vistas for students in their understanding of how gardens function. Also, writing down observations and learning to follow written instructions are essential elements of critical thinking, a skill valued in employees. In this sense, using the scientific method in the garden becomes a vehicle for the practice of critical life skills.

Annotated Bibliography:

Campbell, Lindsay K., Wiesen, Anne., Meristem Forum (2007 : New York Academy of Medicine), *Restorative commons : creating health and well-being through urban landscapes* / edited by Lindsay Campbell and Anne Wiesen., Newtown Square, PA : USDA Forest Service, 2009

Gerlach-Spriggs, Nancy, 1950-, Kaufman, Richard Enoch, 1945-, Warner, Sam Bass, 1928-, *Restorative gardens : the healing landscape* / Nancy Gerlach-Spriggs, Richard Enoch Kaufman, Sam Bass Warner, Jr., New Haven CT : Yale University Press,1998

Hunken, Jorie. , New England Wildflower Society. , *Botany for all ages: learning about nature through activities using plants* / Jorie Hunken and the New England Wild Flower Society., 1st ed., Chester Conn.: Globe Pequot Press

Leslie, Clare Walker., Roth, Charles Edmund, 1934-, *Nature journaling : learning to observe and connect with the world around you* / Clare Walker Leslie and Charles E. Roth ; foreword by Edward O. Wilson ; illustrations by Clare Walker Leslie and others., Pownal Vt. : Storey Books, 1998

Guy, Linda A. , Cromell, Cathy. , Bradley, Lucy K. , University of Arizona. , Maricopa County Cooperative Extension. , *Success with school gardens : how to create a learning oasis in the desert / Linda A. Guy, Cathy Cromell, and Lucy K. Bradley ; with the Maricopa County Master Gardener School Gardening Task Force, Gail Morris ... [et al.] ; illustrations by Erin O'Dell.* , Phoenix AZ : Arizona Master Gardener Press in cooperation with the University of Arizona Maricopa County Cooperative Extension , 1996

Bibliography for Students

Gunnison, Olive Mason, 1888-, *Learning to garden; drawings by Anne Seaman. Foreword by T. H. Everett*., New York Funk & Wagnalls Co., 1948

Sidgwick, Cecily Ullmann , Paynter, Mrs. , Robinson, Winifred Cayley, , *The children's book of gardening / by Mrs. Alfred Sidgwick and Mrs. Paynter; with twelve full-page illustrations in colour from drawings by Mrs. Cayley-Robinson.* , London : A. and C. Black , 1909

Chapter 3: Soil

Performance Objectives

Students will be able to:

- Name the constituent parts of soil.
- Name and explain the nutrients and their roles in soil health.
- Conduct soil tests.
- Compare and contrast poor soil and good soils.
- Make and maintain compost piles.
- Dig effectively in the soil with proper use of hand tools.
- Amend soil in each garden site based on observations of conditions.
- Cite examples of soil contamination.

Assessment will be based on several criteria. Students will:

- Successfully separate the constituent parts of soil by mechanical method.
- Demonstrate to instructor the ability to correctly perform soil amendment.
- Demonstrate to the instructor the ability to correctly handle tools.
- Perform all exercises to completion.
- Work as individually and also as a team.

Lesson
3 - 1

SKILLS

Ability to choose correctly among soil amendments

Ability to correctly assess the quality of soil

Ability to extend mathematics to a specific measurement problem

Digging

Knowledge of basic soil science

Knowledge of different types of soil

Selecting tools correctly

VOCABULARY

Aeration

Amendment

Cultivating

Decomposition

Deforestation

Digging

Drainage

Fertile

Layers

Minerals

Nutrients

Organism

Particle

In the sweat of your face you shall eat bread till you return to the soil, for out of it you were taken. For dust you are and to dust you shall return.

Genesis 3:19

In the South Bronx, the sun is just coming up. The interns have been breaking the thick slabs of concrete sawn out of the sidewalk all week. They dig tree pits by hand, and sometimes use a jack hammer to break through the layer of schist. They are having a competition to see who can break the thick concrete into perfect pieces for filling the wheelbarrows. It is cold. They work in their layers of shirts. Today there is a big group maybe 10. They have worked so hard lately that the gloves on their hands are in shreds by the end of the day.

A semi truck full of trees pulls up to the gate of Hunts Point Multi Service Center. The interns gather around the truck. It looks too large to squeeze through the space.

“It won’t fit,” I say.

“It will fit,” he says.

Here the soil was heavily laced with gravel left over from the foundations of the Hunts Point Multi Service Center

Lorenzo guides the truck into the parking lot. The fender hits the fence post and bends it out of the way just as the sun is peeping over the piles of rusted metal in the junk yard. If the truck were 2 inches wider it wouldn’t fit in at all.

“It’s ok, it’s ok, we will have to fix it later.”

This neighborhood provides 20% of the NYC prison system’s population. Here the students tell me many people are carrying guns. Here there are still overhead wires. The New York City Housing Authority Project–Adams House is right next door across Westchester Avenue. The stores on Westchester Avenue sell things that are not usually found in mainstream America’s grocery stores: piles of plantain, batata, yucca, chorizo, sweet bread, gandules, arepas, pan y guabaya. Everyone speaks Spanish. Passing by the rows of dilapidated houses are teenagers walking to school; this is not a neighborhood of poverty, addiction, crime as it is depicted in the popular media, but rather an area of working class poor with strong ties to the Caribbean.

Like a band of motley revolutionaries armed with picks and shovels, some of the students wear uniforms or parts of uniforms. “The Horticultural Society of New York” and “GreenTeam” emblazoned in stencil. Other newer interns have no uniforms so they (like gardeners everywhere) wear comfortable functional clothes with lots of pockets, dirty, sometimes almost in rags. In the distance the hulks of non-operational factories loom near the greasy filthy water’s edge. A smokestack points to the sky like a giant finger.

A woman comes out of the Hunts Point Multi Service Center and asks, “What are you doing? Are you going to plant something here?”

"We're planting trees, Miss," Lorenzo says in that polite voice of his. She claps and seems genuinely thrilled. The maintenance workers are less enthusiastic and more skeptical: there have been many trees planted here in the past, producing only vandalism and disputes over who should take care of them. Yet they help us they lend us hoses and a wheelbarrow. They are the uncles and cousins of the interns. They can speak the same language.

I cannot keep myself from walking over to where Lorenzo is talking to the woman. Though I know that if I leave now, in their enthusiasm, the interns will rush through some step in an automatic way and then I will have to scold them. But I want to tell her about the project.

The interns are planting trees through a contract that HSNY was awarded by The New York State Energy Research and Development Authority. This tree planting will increase the canopy over areas of high concentration of impervious surface like parking lot and sidewalk as a measure to mitigate the "heat island effect" that drives up energy demand for cooling. The South Bronx seems to glowing in infrared satellite photographs. This is the most difficult thing that the internship project has ever tried to do on its own. It is a small planting—only about 30 trees—yet I have been waking up at 3:30 every morning unable to go back to sleep panicked by fear of having taken on something that will surely fail. That I have forgotten something. I have been warned by people not to do it. And even if someone seems supportive, I suspect them of wanting to see me fail. The project has been beset with delays, changes, new hurdles to jump over. I have a recurring dream of walking along the lonely street of the elevated train rubbing shoulders with South Bronx kids that look like cousins of the interns. As I walk down those cold, lonesome five-o'clock streets, in the distance among the ruins of movie theatres and factories I can see trees.

But first comes the digging: 5 feet by 6 feet by 3 feet deep. Fill with replacement soil according to NYC Department of Recreation spec: compost, sand, topsoil. Choosing the holes is like dousing—take serious veins of shale, mix in generous parts of construction rubble, "clean fill," and clay compressed under hundreds of pounds of concrete. Yet another spot might contain nearly virgin soil. Hunts Point has lots of land fill. Further up in Westchester, we dig with a demolition hammer. Everywhere pinch bars are the primary tool. The 20-yard dumpsters fill up quickly we quarry enough stone to pave the tree pits when we are done. Each area tells its history in its soil.

Soil

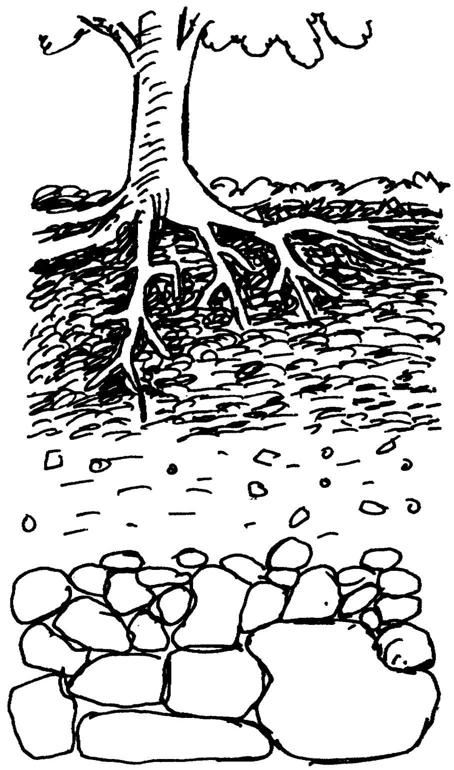
Fig. 1.
A worm's eye view:
Abundant earthworms, millipedes and other soil organisms.
Plants and organic mulch cover the soil surface.
Dark topsoil layer at least 6 inches deep.
Healthy roots with plenty of root hairs.

There are many clues both above and below ground level abut the health of your soil: soil color, humus content, the presence of living organisms and drainage. The landfill soil that predominates on Rikers Island is grey in color due to high concentrations of building materials. This indicates poor aeration with poor drainage. After introducing compost and mulch to the soil, the amount of organisms living in the soil increases and the color gradually mellows towards a dark brown that is indicative of better drainage.

Soil is earth's superficial covering. Soil consists of minerals like clay, sand or bits of rock, decaying parts of plants and animals, water and air. It provides Earth's rocky skeleton with a loose covering, which varies widely from place to place. The composition of the soil is contingent upon the kinds of geological materials from which it is made, the kind of vegetation growing on the soil, and human activities which may make artificial alterations to the soil. Plants take root and grow in soil, animals graze and make their homes in soil, and humans plant crops for food in the soil and build on the soil.

Plants rely on the soil to get the water, nutrients, and minerals they need. They grow roots to get to the layer of soil containing the right conditions for growth. Soil has three different layers. The top layer, or topsoil, is rich in organic matter. The second layer is mostly organic but may also contain some rocks. The third layer is comprised mainly of rock, which lies under the soil.

Soil holds water and keeps it from evaporating. The availability of water from the soil is critical to productivity of the soil. How long and how much water is held depends on the type of soil. Clay soil, which is a heavy compact soil, holds water for a longer period of time, while a sandy soil is usually incapable of holding enough water for plant growth.



Plants are provided with nutrients from decaying plants and animals found in the soil, while crushed rocks provide the minerals needed for plant growth. Worms and insects found in the soil help in by breaking down this decaying material, thus enriching and aerating the soil. Passing through the bodies of these natural decomposers changes the texture and quality of the soil.

Scientists take samples of soil and group them according to their general characteristics. They draw pictures of the land that they call soil profiles. The picture emphasizes the properties of the soil that can be seen, felt or measured.

Soil undisturbed by human tillage or deforestation preserves its balance of humus by decomposition and decay of plant and animal bodies, thereby allowing a wide variety of plant, animal and insect species to exist.

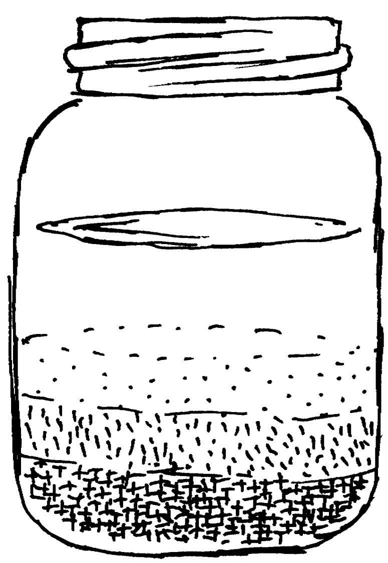


Fig. 2. The relative proportions of sand, silt, and clay in the soil is referred to as soil texture. Exercise 1 explains how to separate soil into its constituent parts.

Exercise
3 – 1

CONSTITUENT PARTS OF SOIL

Objectives

1. To understand that soil is made of many different things, such as minerals like clay, rock and sand, decaying plants and animals, air, and water.

2. To separate and identify the composition of different types of soil.

Materials:

Soils from several different locations, jars with lids for each kind of soil, labels, marker, water, and large spoon.

Procedure

1. Make two columns on a large sheet of paper. Label one column before and the other after.

2. Ask the students what they know about soil. Write their responses in the "before" column.

3. Collect and label bags of soil and other materials from each of several sites. Explain that they will be doing an experiment which will show what each of these soils is made of.

4. Place 1/4 cup of soil in each jar and fill it with water. Secure the lid and shake the jar well to mix the soil and water. Label the jars with the place where the soil sample was collected. Set them aside for a few days so they can settle into different layers.

5. Have the gardeners or students discuss the composition of the different layers in each jar. Compare the jars.

6. Divide the students into groups and allow them to draw their soil's profile in their eco-journals and label the different layers.

7. Initiate discussions about the type of plants were growing at each site in the various soils collected, referring to the portfolios to aid memory.

8. Review with the students what they now know about soil. Record their responses under "after" in column two.

Lesson
3 - 1

Exercise 1

SKILLS

Drawing

Labeling

Observation

Sample collection

VOCABULARY

Debris

Humus leaf litter

Leached nutrients

Solid bedrock

Subsoil

Topsoil

Weathered bedrock

1. Testing the soil. Samples of soil from various parts of the site should be tested for standard nutrients by the local extension service lab. Any bare spots should have a soil sample collected and tested separately. If the soil is bare, there are no plants growing. If there are no plants growing, why? Is the soil poisoned? You need to know before you plant there. (This does not include spots that are bare because there was something covering the spot, such as a piece of wood or plywood.) It may be necessary to dig out a section of soil if it is visibly contaminated.

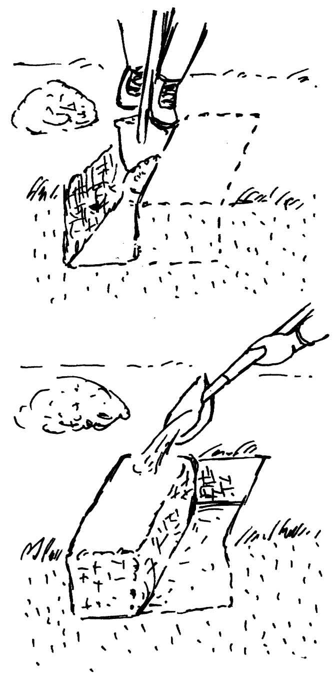


Fig.2.
Double Digging. Soak the soil with water a few days before, remove weeds and sod. With a spade dig an area 1 foot wide by 1 foot deep. Deposit the soil into a wheel barrow. Dig a trench alongside and deposit the soil you have just dug. It's back breaking work but keep at it until you have treated the entire area in this way.

2. Preparing the soil for planting. Many people will rototill a new site in order to prepare it for planting. Rototilling is a very effective method of loosening the soil and killing weeds so that the seeds may be planted. It is also an effective method of adding compost and fertilizers into the soil. However, rototilling also may kill some of the earthworms present in the soil. Earthworms are terrific natural aerators and mixing agents, and for densely compacted soil, rototilling may not be an option. That is why there is still no substitute for French digging (as shown in Fig. 2).

When we discuss soils, we are talking about the abiotic factor that furnishes water and minerals to plant roots. Soil type is often the limiting factor in the distribution of plants. How does soil structure influence the availability of water and minerals? The soil has a texture that results from the combination of the **organic matter** in the soil with the **mineral material** present. The organic material results from the **decomposition of plant material** in the soil. The mineral materials are based on the **size of the soil particles**. The finest particles are called clay, the next finest silt, then sand, and finally gravel, which is the coarsest. The various combinations of these substances give rise to the various kinds of soils.

How does a soil absorb and hold water? When it rains, the spaces between the soil particles fill with water.

In this condition, there is no air present from which the roots may obtain oxygen. After the excess water (called the **gravitational water**) has drained off, what is left is a shell of water around each soil particle. The soil at this point is said to be at **field capacity**. The plant roots absorb this water for plant use. The water is held to the soil particles by hydrogen bonding.

As the water is absorbed by the roots, the shell of water around each soil particle becomes thinner. And finally, when almost all of the water has been absorbed by the roots, the force needed to remove the water from the surface of the soil particles becomes so great that the roots can no longer absorb any more water.

Exercise 3 – 2

NATURE AND PROPERTIES OF SOILS

For this exercise, you will work in groups. Each group will prepare a report. Reports should include the data sheet provided on this page.

Materials:

1. Soil samples from the sites that you wish to test
2. Measuring cups capable of measuring in milliliters
3. A torch
4. An oven
5. A cast iron pan
6. Several metal containers such as pie pans
7. A scale capable of making fine measurements in grams

Procedure

1. We will do this by first **wetting** a sample of soil. Write down how much water you have used to wet your sample.
2. When the gravitational water has run off, we will **weigh the sampl**e and its container. We will then leave the soil to **air-dry over night**. The air-drying approximates the amount of water removed from the soil by the roots.
3. The second day, we will **weigh the sample** and then place it **in an oven**. This will remove the remaining water from the soil. The soil will remain in the oven overnight.
4. The last day, we will take the oven-dried soil, **weigh it**, and **heat it** with a torch in a cast iron frying pan to **get rid of** all the **organic material** in the soil. This must be done with caution. Be sure you **wear goggles** and stand well back when you are heating the soil. It will have to be stirred while you heat it. Let the soil **cool thoroughly** and then **weigh it** one last time. This will give you the amount of mineral material in the soil.
5. We will record these findings (see the attached data and calculation sheet).
6. The organic material in the soil is important in helping plants absorb minerals. This humus gives the soil a “crumbly” texture and ensures the soil is open and well-aerated. A soil without organic material is generally poor and very hard.

Lesson
3 - 2

Exercise 2

SKILLS

Applying mathematical processes to observable phenomenon to draw conclusions

Heating with oven and torch

Measuring

Recording

VOCABULARY

Approximates

Grams

Gravitational

Milliliters

Mineral material

Proportion

Roots

Wetting

Data Sheet For Exercise 2

Weight of wetted soil in container:	SOIL WEIGHTS:
Weight of air-dried soil in container:	Wetted Soil:
Weight of oven-dried soil in container:	Air-dried Soil:
Weight of container:	Oven-dried Soil:
Weight of wetted soil:	Heated Soil:

Weight of air-dried soil: ____________

Weight of oven-dried soil: _______________

Weight of oven-dried soil in cast iron frying pan: ____________

Weight of heated soil in cast iron frying pan: _________

Weight of cast iron frying pan: ____________

Weight of heated soil: ____________

Calculations

How much water is available to plants? ___________ ml/gram of soil

How much water is present at field capacity? ___________ ml/gram of soil

How much water is not available to plants? ___________ ml/gram of soil

What is the percentage of organic material in the soil? _____________ %

Understanding Your Soil

Soil Profile	**Amendment**
Sandy	Topsoil: If your soil is sandy topsoil may help it to retain moisture better. Topsoil is available from commercial garden centers.
High Amount of Clay	Sand: Soil with a high amount of clay in it benefits from sand. When you add sand, also add organic matter.
Lots of Sand or Clay	Spagnum Peat Moss: Will improve the texture of soil that has too much sand or clay. It is sold in bales or bags. It has no nutrients but it composts over time.
Average Soil	Humus: Organic matter that will improve the texture of almost any soil. It lightens up dense clayey soil, and plugs up the holes in sandy soil. It is available from garden centers.

COMPOSTING:

One of the most basic and fundamental aspects of organic gardening is the use of compost. Adding compost to the soil increases the organic content of the soil, improves the structure of the soil, permits better water retention in the soil, and facilitates mineral uptake by plants. It may also add a small amount of nitrogen to the soil, but it is not a fertilizer in the common sense. Excessive amounts of compost may actually result in nitrogen deficiency. If you are going to have an organic garden, you must understand what compost is and how it is made.

Compost is partially decomposed organic material mostly derived from plants. Compost is usually not purchased, but rather made at the garden site. If you do purchase compost, it is often sold as “humus” or “loam.” But it is so easy to prepare that there is little advantage to buying it other than saving time. Compost is prepared by simply piling scrap vegetable materials together. These can be grass clippings, leaves, waste foods (but vegetables only!), weeds and any other plant materials you can think of. A small amount of soil is mixed in to furnish the correct microbes, some water is added to dampen the entire pile and then you just let the pile sit until it has partly decomposed or “composted.” Sounds simple, right? But there are a few other considerations that we had best mention.

Composting at Rikers Island

If you just leave the pile sitting there, it may blow away or be disturbed in some other way. You need to make a compost bin to contain the materials. We have a store near our school that is only too glad to give away pallets. Pallets are ideal for a compost bin because they have large slits that let air into the compost. We have obtained materials for several bins and it has not cost us anything. All we did was to lash four pallets together with nylon cord to form a bin. You can also buy a number of different kinds of compost bins, but it is good for the class to work together recycling old pallets.

The more finely divided the plant material at the beginning, the quicker the compost will form. We have had good luck with running a rotary lawn mower over a pile of leaves and weeds, and catching the resulting chopped-up materials in the bag. This material is then added to the compost bin.

The one problem you may have with your material is it getting too compacted and/or too wet. If this happens, you do not get compost, you get rotted plants. And this material will not help your garden. So you must aerate the compost. This is why a bin that has slits in the side is ideal. In order to aerate the compost, you normally turn the entire mass in the bin over with a spading fork every few days. We arranged our bins so that the front of the bin swings open like a door. This made turning the compost very easy. As the compost forms in the bin, the vegetation decomposes. Soil micro-organisms will feed off the vegetable matter, raising the temperature of the inside of the compost pile to from 120âF to 160âF. This decomposition needs to be aerobic, thus the need to turn the compost. You must supply water, but if you over-water, you will eliminate the needed air and decomposition will become anaerobic. Finally, when the compost is finished, it will be black and crumbly—not quite like soil, but definitely no longer identifiably plant material. Usually at this stage, we run the compost through a sieve made of hardware cloth and some 2 X 4s. (Available at any building supply store. They are easily constructed. Do not make the frame too large or the students will have a difficult time shaking it.) The sieved material we add to the garden, and the residue we put back as starter material for the next batch of compost.

Exercise
3 – 3

COMPOSTING

Compost is basically decayed organic material. When mixed with mineral soil, it facilitates mineral uptake by the plant and increases the water-holding capacity of the soil. The organic portion of the soil is extremely important for developing good soil, and is extremely easy to produce. Later, the principles of composting will be used to build a large compost bin.

MATERIALS: (per group)

- 2 identical plastic containers with lids (at least 2 quarts)
- A selection of vegetable scraps
- 50 worms
- 6 oz. of raw hamburger

PROCEDURE:

1. Each group should punch or cut six holes in the lids of the containers.

2. Each group will set up the two containers as follows: Shred all of the vegetable scraps and make sure that they are well-mixed. Divide them into two equal piles and add 2 oz of hamburger to each pile. Mix each pile separately and place in the two plastic containers. Water each container with the same amount of water. Use enough water to moisten the materials but not enough to produce any liquid in the bottom of the containers. To one container, add the 50 earthworms.

3. Place the containers in a cool, dark area such as a closet.

4. Observe the composting vegetation every other day.

5. One group should re-mix their compost once a week.

6. One group should re-mix their compost twice a week.

7. At the end of six weeks, each compost bin should be sifted and the materials that pass through the screen placed back in the container on top of the material that is not fully broken down. (Be gentle when you do this, you do not want to kill your worms.)

8. After about two more weeks, the compost should be finished.

QUESTIONS for THOUGHT:

1. Why add the hamburger?

2. Why punch the holes in the lid? Why use a lid?

3. Which bin did a better job? Why?

4. Occasionally, there is too much water in the bottom. What results?

Lesson
3 - 3

Exercise 3

SKILLS

Adhering to a schedule

Caring for worms

Individual responsibility

Observation

Recording

Working as a member of a group

VOCABULARY

Compost

Graph

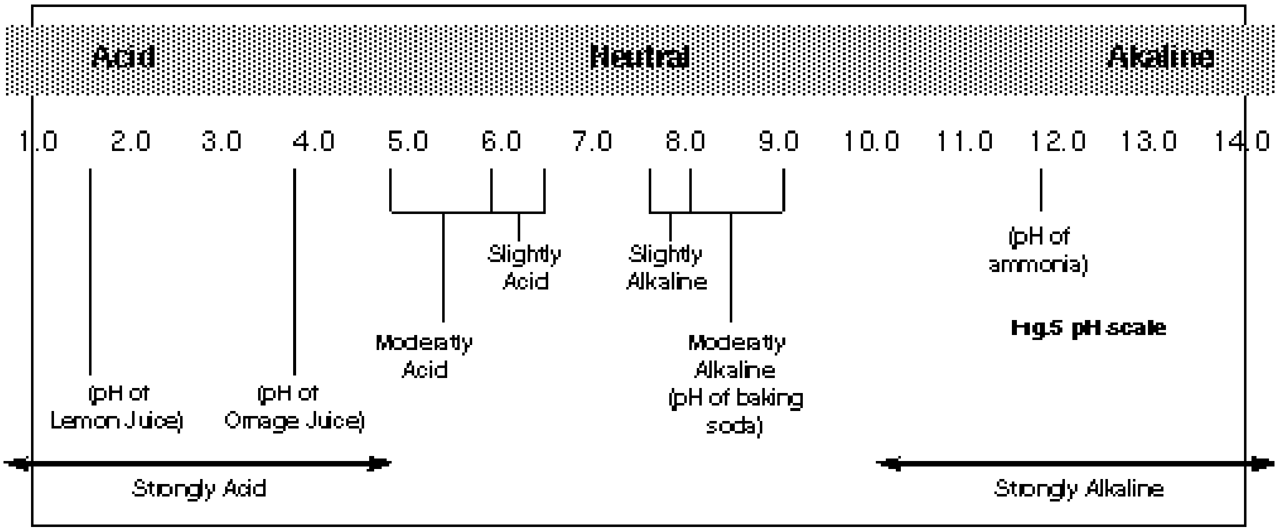


Fig.5 pH scale

Soil pH Demystified

Knowing the pH of your garden soil—whether it is alkaline or acidic—is instrumental to knowing how well plants will grow in their designated garden space. Acidic soil can tie up phosphorous, while alkaline soil immobilizes iron, boron, copper, manganese, and zinc. The explanation is relatively simple: on each soil ped (particle), there are negative and positive chemical charges. Since hydrogen is positively charged, excess hydrogen will attract negatively charged ions, including sulfur and phosphorous. These ions with their total negative charges create soil conditions that have an acidic pH. Alkaline soil contains negatively charged hydrous oxides, which attract positive charged ions such as calcium, copper, iron, and boron.

The pH scale ranges from 1 to 14, with neutral at 7, acid below neutral, and alkaline above. Any movement from one number to the next is an exponential increase in the level of acidity or alkalinity of the soil. For example, a soil with a pH of 5.5 is ten times more acidic than a soil with a 6.5 pH and a hundred times more acidic than a soil with a pH of 7.5.

Sumary of mineral elements needed by plants

Macronutrients

Element	**% of dry weight**
Nitrogen	1 -- 4 %
Potassium	0.5 -- 6%
Calcium	0.2 -- 3.5 %
Phosphorus	0.1 -- 0.8 %
Magnesium	0.1 -- 0.8 %
Sulfur	0.05 -- 1 %

Most plants, especially garden variety vegetables, thrive in a pH slightly acidic to neutral. However, for shrubs, trees and perennials, their native environment will predictably dictate the type of soil they grow best in. Plants from wet environments generally do best in acidic soil (bogs have extremely acidic soil conditions). Rhododendrons, azaleas, blueberries, and heather are a few examples of acid-loving plants. And plants native to drier systems prefer more alkaline conditions. Cacti, for example, need a high pH that is typically found in desert systems. Adding amendments such as limestone (which has positive charged calcium ions that displace the hydrogen ions) can balance acidic conditions, just as adding sulfur-based ions can acidify a high base or alkaline soil.

Exercise
3 – 4

Measuring soil pH

A soil testing kit that can measure both pH and nutrient contents is an excellent way to familiarize students with the chemical and biological activity of their prospective garden soil. Amendments that generate good soil structure as well as conditions that support a healthy population of earthworm and micro-biota activities will buffer narrow swings in soil pH and produce healthy plants year after year.

Materials:

- 1 quart jar or small pail
- trowels

Procedure:

1. Select the site to be tested.
2. Choose six different areas of the garden.
3. Combine the soil samples into one container and mix well
4. Use a commercially available pH testing kit to determine the levels of acidity or alkalinity.
5. Refer to the table on this page to create a strategy for raising or lowering the pH of your soil.

Raising or Lowering pH

Material	Soil type	Starting pH	pH after change	lbs per 100 sp. ft.
Limestone	Sandy loam	6.0	6.5	5
Limestone	Sandy loam	5.6	6.5	8
Limestone	Silty loam	6.0	6.5	10
Limestone	Silty loam	5.6	6.5	15/

Try using elemental sulfur to correct alkaline soil. As in the case of acid soil there are no hard and fast rules. Add a little at a time and never more than once per year. Test often and carefully.

Lesson

3 - 4

Exercise 4

SKILLS

Altering pH levels

Interpreting results

Maintaining consistent pH levels

Measuring

Observation

Performing soil testing

VOCABULARY

Acid

Acidic

Alkaline

Base

Limestone

Loam

Micro-biota

Nitrogen

pH

Phosphorus

Potassium

Silt

Sulfur

Fertilizer and Soil Amendments

In most natural systems dominated by plant communities, nutrients return to the soil when plant leaves, stems, and roots die and decompose. This continuous release of vital nutrients is generally slow enough to prevent excessive uptake by plants and helps prevent nutrients from leaching out as subterranean run-off from heavy rains. Replicating this system with a layer of mulch and compost is often the most beneficial method of improving the soil, adding nutrients and texture as well as promoting local conditions for soil micro-fauna. Other natural amendments or additives include bone meal, blood meal, woodash, eggshells, limestone, and gypsum (see natural fertilizers).

Earthworms are always a good indication of healthy and productive soil. Earthworms transform decaying leaves and roots into nutrient rich castings; their journey through the substrate aerates the soil and brings mineral particles from below to mix with organic matter on top. A square meter of garden soil may contain as much as 3 pounds of live worms, and their constant activity is instrumental in creating productive, fertile soil.

Today, with so many natural amendments available in the market place, there are many disadvantages to using synthetic or chemical fertilizers. Chemical fertilizers are mobile and can readily leach out into nearby bodies of water, generating conditions that are often harmful to aquatic systems. High applications of fertilizer can "burn" plant roots, or if they are heavy in nitrogen like many grass fertilizers, they can produce excessive growth in flowering plants at the expense of fruit and flower production. Chemical fertilizers are simply quick injections of nutrients that, on their own, do not sustain good soil conditions over time. Conversely, fertilizing soil without amending it will eventually reduce the soil's fertility—decreasing the quality of its texture, and depleting the microorganisms on which good soil depends.

Natural Fertilizers

Besides the fact that most programs are strapped for funds, much of the time there is another reason for going to the trouble of mixing your own general purpose organic fertilizer. Your students will realize that it is not necessary to rely on commercial preparations. They will also learn more about the nature of fertilizer by studying the component parts.

Use one from each category mixed with one amendments from the other two categories in the proportions shown (it’s also a good way to promote math literacy). For example:

Nitrogen (N)

2 parts blood meal
3 parts fish meal

Phosphorus (P)

3 parts bone meal
6 parts rock phosphate or colloidal phosphate

Potassium (K)

1 part kelp
6 parts greensand

Whether synthetic or natural, store-bought fertilizers list the percentage of nitrogen, phosphorous and potassium present as a ratio. This helps the gardener apply the most beneficial amount required by plant types. For example, a general fertilizer for perennials or flowering shrubs may contain a NPK ratio of 20-20-20. A fertilizer for bulbs is typically 0-20-10, since the plant's energy is focused on root and flower development and not leaf formation. Grass, on the other hand, will contain mostly nitrogen at 30-0-10.

Soil is dynamic matter, a strange blend between animal activity, mineral weathering and organic decay, instrumental to sustaining life on Earth. With only six inches of fertility, a thin mantle of mixed organic crust covering the planet's surface, soil has been severely damaged by poor land use practices throughout the world. Replenishing this resource begins in the garden, for here we learn to be stewards of our own garden system.

Nutrients in the Soil

We often think of plant food as the carbohydrates produced by plants through photosynthesis. But apart from the carbohydrates produced by sunlight, plants also need 16 different nutrients to grow, 13 of which are derived from soil. The other three—oxygen, hydrogen, and carbon—are found in water and air. Macronutrients, the nutrients plants use in the greatest amounts, are nitrogen (N), phosphorous (P) and potassium (K). When these three nutrients are available to plants in water-soluble form, soil is considered to be relatively fertile or "complete."

Nitrogen is essential for leaf and stem growth and its presence results in lush green plants. Most nitrogen is obtained from decomposed plant matter or manure. Leguminous plants such as peas and beans, or clover are able to convert nitrogen from a gas into nutrients through bacteria at their root nodes. These nitrogen-fixing plants make a good live or "green" manure that can be planted and then tilled into the soil. Nitrogen-deficient plants often have yellowing leaves, where discoloration starts at the tip and progresses towards the stem. Spindly, stunted growth and dying stems or branches are also telltale signs.

Phosphorous helps develop strong roots and colorful flowers, promotes winter hardiness, resistance to disease, and increases the vitamin content of fruit and vegetables. Poorly developed seed, leaves that are purplish or poorly developed are often a result of phosphorous deficiency.

Potassium promotes cell division and growth and helps the plant metabolize other nutrients, especially nitrogen. It also aids in the production of starches, oils and sugars for fruit, increases tolerance to drought and encourages resistance to winter cold and disease. Sterile seeds and leaves that turn crisp at the edges, then brown are often in need of potassium.

Secondary or micronutrients consisting of calcium, sulfur and magnesium are used by plants in smaller quantities and are generally available to the plant. Calcium helps with tissue formation in the plant's meristems by aiding in the synthesis of pectin—the "glue" bonding cell walls. Both sulfur and calcium help change the chemical nature of soil by raising and lowering the level of pH (see under pH). Trace nutrients including copper, zinc, iron, boron, molybdenum, and chlorine all play a role in activating enzymes that aid in the metabolism of cell division and plant growth.

Starting From the Ground Up

The exercises in this lesson are not an ends in themselves but rather comprise deeper investigations of the understanding that comes from the experience of hands-on gardening which is the basis of this curriculum. Vegetable gardens, bird, butterfly, bee, herb, arbors, shade gardens and orchards are all unique: all have unique light, water, and design considerations. They are all linked together by their reliance on good soil. Creating and renewing productive fertile soil is the gardener's ongoing concern. Make it your goal and you will be rewarded. Do your soil work every year with composted manure or green vegetable manure in the last winter and early spring. Work it in deep. The mulch that you place in your garden this spring will cool your soil in the summer, retain moisture through out the drought season and warm it in the winter. Then it will decompose and become soil for next year. The tools are also simple: good long-handled round-pointed shovels, broad-bladed pick, cultivator, hard and soft rakes and a good wheelbarrow—the kind with solid rubber tires is best.

Depending on what condition the garden space is in when you begin your work, you will face varying challenges. Working in the backyard of a hundred-year-old brownstone, you will be working in almost virgin soil. If it was the first building in that lot, you are lucky. If it is an old building, you are luckier. In 1890, labor was in expensive but materials were dear. You will find scarcely any building debris. Even in large apartment houses, the courtyards of yesteryear tended to be filled deeply with good soil. In buildings built recently, you will find a evidence of a different ethic. Labor is dear and materials are disposable. At the end of the day, workers often dump leftover mortar into the area set aside for the garden. As the cost overruns pile up, the garden is usually the last item to be considered. Often a thin layer of soil-of-the-day will have to suffice over a substrate of broken brick, gravel, chunks of concrete and sand. If the building stands on the site of several previous buildings, or in the case of most community gardens which are planted on the sites of inner city vacant lots, you will be gardening on the remains of a building that was thrown down into the cellar. You will dig up brick, mortar, appliances, flooring, trash, furniture and depending on the site, oftentimes beautifully carved stonework that speaks to us of the people who lived in other times.

Vegetable gardens must be clean. You can have your soil tested by a local university, and the U.S.D.A can make referrals. Vegetables are forgiving. They can thrive in 1 foot of topsoil with plenty of compost. Scrape away landfill, then build up a raised bed. The bigger the plant, the more soil work you will have to do. Lawn and perennial beds require about 1 foot of good soil. Depending on the plants, holes can be amended individually. Shrubs require breadth. Dig a hole 2 times the width of the root ball and amend it thoroughly. Evergreens like a bit of acid. Vegetables like balanced ph. Where there was a lot of building debris, you will find soil that tends toward base due to the lime in the cement.

Street trees are a special planting because the soil in which they are planted has often been compacted under hundreds of pounds of concrete for decades. NYCDPR requires the removal of at least 90 cubic feet of existing soil to be replaced with DPR spec mixture of topsoil, compost, and sand. You will need a dumpster if there is going to be a lot of planting. You will require permits for planting, opening a tree pit, and parking a dumpster on the street. The sidewalk will have to be opened with a saw, then broken in bits with sledgehammers. It requires team work.

But what if it is just isn't possible to remove enough soil to create pristine beds? Can a garden still exist? Yes. Many times we have had poor soil to work with and plenty of it, for example, at NYC Housing Authority sites. Amend it year after year with compost. Double or French dig it. Remove the rubble and debris. Aerate the soil and add peat. Dig at least to the depth of one shovel deeper if you can. Always step backwards as you work so as not to step on your own work and compress it again. Plant from back to front to avoid stepping on your planting. In time, you can make even poor soil into good soil. It may not be vegetable gardening soil; for that, you will always need to make raised beds if there is any doubt in your mind about soil quality. But it will be soil.

Teachers' guide to lesson plans

All of these lessons are designed to support the work that you will do it the field: amending soil at various projects and maintaining healthy soil at other sites. The curriculum is designed to create a holistic, experiential learning process. The core work is learned by the student in the field at work making and caring for gardens. These exercises are especially useful for students most inclined to physical activities. If a student is very well-developed in the theoretical aspects, then they may get greater benefit from digging in the earth than measuring its pH by chemical processes. The intellectual exercises are a way to balance the work that goes on in the field throughout a year of planting and caring for gardens. The team work that comes from agricultural work provides the third element of the triad that helps the student learn to truly observe the world around them. Once they have learned to do this, what they learned in a month before, they will learn in a week and what they learned in a week, they will learn in a day. Once they have awaked to observation, learning will proceed rapidly. And when they have begun to truly understand the laws of nature that guide the gardener, they can begin to see themselves as part of that system and care and nurture their own development.

Lesson plan #1: Nature and properties of soils This exercise takes the form of a laboratory exercise which can be reproduced as is. The students are asked to submit a report for each group. This encourages group cooperation, development of communication skills and responsibility within each group. The success of the exercise depends largely upon how well the students cooperate. The teacher will have to supply one or more soil samples for the class. You may ask students to bring in samples of soil from home, but it is a good idea to have at least one sample that you provide. This sample should have at least 15 - 20% organic material. You can make sure of this by adding organic material such as compost to the soil. Students do not need a great deal of soil. Usually samples are too large rather than too small. Remember, only enough soil is needed to fill a Petrie dish.

Lesson plan #2: This lesson plan requires the use of special materials which you may not have access to such a torches. It is also possible if you have access to an oven to heat the soil in an oven until it is dried out. or if that is not possible even a small electric cooker or gas ring will work as long as you have a cast iron skillet to heat the soil in. The purpose of these lesson plans is not to create a regimen that must be followed exactly but rather to provide a framework for experimentation that can be adapted to the circumstances on hand. The most important aspect is to promote the idea of comparison. Comparison between soil that is air dried and soil that has been purged of all organic matter. The hope is that we will create understanding of the living complex nature of soil by a process of reduction. First reducing it by the elimination of water then by the elimination of organic matter until all that we have left is mineral. And of course scan the soil carefully to remove living creatures though I cannot be avoided microbes will be subjected to the experiment as well though most will not survive the initial air drying process still students should be made aware of this.

Lesson plan #3: Composting. This exercise really is designed to be completed before the gardens are started. It can be done any time during the school year, but is probably best attempted during February and March. The vegetable materials to be composted can be collected by the students. Have each student save all of their family's vegetable scraps for one week and then bring them to school. They may be kept in the refrigerator or freezer in a plastic bag while they are being collected**.** The plastic bins to compost in are the type of plastic storage boxes that are sold in discount department stores and Woolworth's (about 16"L x 10"W x 8"H). Sometimes these type of plastic boxes may be obtained used from fish stores or from restaurants that sell a lot of fish. I have used these fish boxes a number of times. All they need is a thorough washing to eliminate the fishy smell. Later on in this curriculum, we will discuss how to build large compost bins that can eventually replace commercially-produced compost for at least some of the needs of the garden.

Bibliography

Ebeling, Eric., *Basic composting : all the skills and tools you need to get started* / Eric Ebeling, editor ; Carl Hursh, environmental educator and consultant ; Patti Olenick, soil scientist and consultant ; photographs by Alan Wycheck. 1st ed., Mechanicsburg, PA : Stackpole Books., 2003

Parnes, Robert., Fertile soil : a grower's guide to organic & inorganic fertilizers / by Robert Parnes., [2nd ed.]., Davis Calif. : AgAccess**.**, 1990

Pfeiffer, Ehrenfried, 1899-1961., Heckel, Fredrick, tr., Bio-dynamic farming and gardening; soil fertility, renewal and preservation [by] Dr. Ehrenfried Pfeiffer; with 18 illustrations., New York Anthroposophic press; 1940

Chapter 4: Building a Garden

Performance Objectives

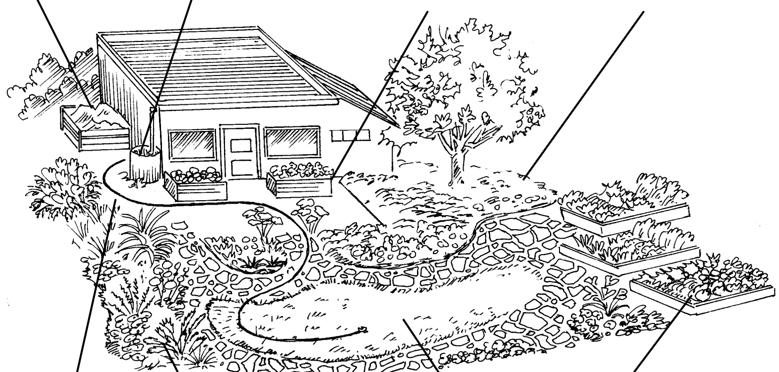
Students will be able to:

- Create an accurate scale map of a garden site by pacing out distances and transferring measurements to graph paper.
- Demonstrate practical knowledge of the components of a garden by identifying and describing them.
- Record sun and shade exposure conditions.

Assessment will be based on several criteria:

- Each of the conditions of the exercise must be satisfied.
- A demonstration of competent garden planning
- Discretionary credit given for creativity, originality, and evidence of mathematical thought.
- Each member of the group will be evaluated individually. A group grade will not be given.

Fig. 1.



Lesson
4 - 1

SKILLS

Ability to extend mathematics to a specific measurement problem

Ability to synthesize information

Creativity

Formatting and presentation skills

Knowledge of basic garden components

Research skills

VOCABULARY

Access

Borders

Graph paper

Ground cover

Lawn

Mulch

Paths

Raised beds

Seating

Shade

Sun

Every garden space that you work on is unique. Whether HSNY student inmates are working at the Rikers Greenhouse or HSNY inters are working at a community garden, school, private residence, or non-profit partner project, they are developing techniques in the limitless nature of gardening and horticulture. Each day during 2007/8 HSNY interns met at the Whitestone Branch Library of the NYC Public Library System. Under the supervision of HSNY instructors, they engage in all of the stages of development required by this NYC capital improvement project that turned a neglected parking lot into a serene meditation and learning garden with perennials, trees, paved patios, seating, water features, and handicapped access.

Everything must be perfect when you are constructing “form work” (even the word “form” is suggestive) used to create molds for about 7 tons of concrete to create benches 9 feet long by 17 inches high by 18 inches wide to a tolerance of 1/16 of an inch in order to hold a veneer (or “façade,” again another suggestive work) of 1-inch-thick slate.

Fig. 2. Whitestone Library before: Autumn 2007.

Working with 3 teams of 3 interns each—1 welding, 1 doing soil work, and 1 doing carpentry—the work progresses throughout the fall and winter as we adhere to strict schedules and carefully follow the plans created by an architectural firm and approved by NYC Dept. of Building and Construction.

HSNY interns take the large pieces of material from a designated stack. Bringing them to the work table (often around an obstacle course of trenches and temporary supports) requires the body to be conditioned and nimble. You have to really feel your body. Next the mind must measure all the pieces in real space using a combination of ruler and framing square. For many of our students, this was their first experience of working with a ruler and carpenter square.

Teamwork is everything. The mind and the hand must work together to cut the pieces with a power saw—it is very dangerous work, requiring 2 interns to hold the material, 1 to cut it, and me to support the cut-off piece. Then switch electrical cords and attach the screw guns. Secure all the pieces. The 1 that cut now holds. The 2 that held now screw. Bring the pieces to a pile and stack in alternate positions so as to make a stable stack or mass. Have you ever considered how many maneuvers and calculations go into making a stable load out of irregularly shaped objects?

Then do the whole thing over but with each person moving one place to the left as it were and taking over the responsibilities of his neighbor. After a few hours of this, it is a pleasure to dig out a stump or condition soil.

Never do the same thing 2 days in a row. Adaptation is important—maybe that is what being an adult is about. Already the interns are more or less conditioned in their bodies; the mind is more difficult, and the emotions are the most difficult of all. Exercises that help interns to feel all these “centers” working together requires effort on the part of interns and instructors. It certainly helps that they are receiving a small stipend for their participation in this income-generating project.

Natural Features of a Garden Site

Exposure to sun:

- Full sun
- Part sun

Density of shade

- Dense shade
- Dappled shade

Principal Types of Gardens

- Container gardens
- In-ground gardens

Fig. 3. The garden space at Whitestone Branch Library, completed Spring 2008: a professional-quality garden.

The internship serves a compensatory function; it gives a person a chance to return to the mistakes of the past and work them out a new way. The great thing about working in horticulture like this is that we can benefit from the task of understanding what is below us (organic life) and what is above us (cosmic influences like climate, time, exposure to sun and shade, soil conditions, rainfall) and how we stand somewhere in the middle—planning, observing, doing (which take the place of wanting, sleeping, and imagining)—just as at work, we must consider the person above us (supervisor) and the person below (assistants.) or in building: the supplier of raw materials and the person that must follow us to do the finishing work. Except that horticulture is unique in that we study the laws of nature and life itself, both as directed from above us (those forces of nature that control life) and from below (those elements of nature whose well being we are responsible for preserving and maintaining).

HSNY interns work at many projects of our partner groups developing healing and learning gardens. Gardening projects like Bailey Holt House rooftop vegetable gardening project for individuals with HIV/AIDS and Common Ground, where formerly homeless residents of this converted landmark hotel have taken over the landscape contract from a commercial contractor, Martin Luther King and Redhook Seniors' Center of New York City Housing Authority, and African American Planning Commission's Serenity House for women and children seeking stable housing all have their own special curriculum. All of these gardens are unique, but all are made up of the same basic components: plantings of perennials, annuals, or vegetables, raised beds, containers, lawns, paths, patios, seating, and rain harvesting equipment. We are committed to helping all our groups find ways to continue gardening in their own unique way.

Fig. 4. 5 Star Community Garden Before and After

Fig. 5. P.S. 57 The Garden of Dreams before and after. Students from the elementary school helped HSNY instructors design this garden space. HSNY interns and P.S. 57 students transformed the underutilized courtyard into a learning garden with vegetable beds, evergreens, fruit trees, and a waterfall.

Exercise
4 - 1

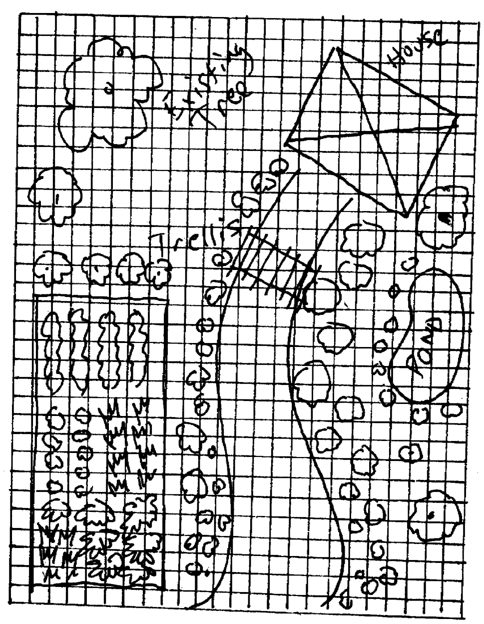
CREATE A BIRD'S-EYE VIEW OF YOUR SITE

Materials (per student)

- 1/4 inch graph paper
- Pencils and erasers

Procedure for the entire group

1. In the case of a large space, divide the garden into as many equal areas as there are students, including natural and man-made features in each area.
2. Explain the use of graph paper to the group. 1/4 inch on the graph paper equals 1 foot in the garden is a good ratio
3. Explain the method of pacing off measurements. 1 adult pace is approximately equal to 3 feet or 3 boxes of the graph paper
4. Explain how to designate principal features of the garden with geometric symbols. Remember that trees with large canopies should be plotted by their trunk location as well as the breadth of their canopies.
5. Explain how to use a principal point in your quadrant as a starting point and to make as many measurements starting at that point as possible.
6. Make observations of the light conditions as well as the principal features of the soil—if it appears to be sandy or clayey, loamy, well-drained or soggy. Note the elevation above or below fixed points like sidewalks or adjacent buildings.
7. When all have completed their maps, join them together to form a bird's-eye view of the garden.



Lesson
4 - 1

Exercise 1

SKILLS

Approximating

Mapping

Measuring

Observation

Technical drawing

Visualizing

Working with symbols

VOCABULARY

Bird's-Eye

Breadth

Clayey

Elevation

Features

Loamy

Silt

Chapter 5: The Vegetable Garden

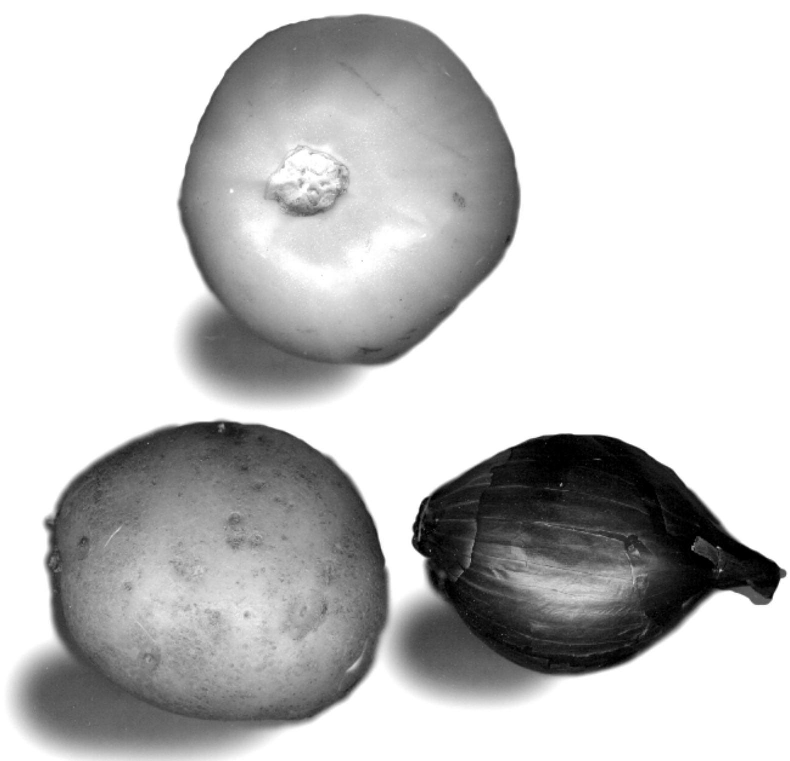
Performance Objectives (by now your soil work will be completed as discussed in Chapter 4)

Students will be able to:

- Select the site for the vegetable garden using criteria from the lesson.
- Plan and plant the vegetable garden site.
- Keep the vegetable garden site weed-free and well-watered.
- Harvest mature healthy fruit, root, and leaf produce.
- Prepare the site for next year using criteria from the lesson.
- Cite examples of environmental quality.
- Cite examples of environmental damage.
- Compare and contrast organic methods with chemical methods.

Assessment will be based on several criteria:

- The site plan must meet all criteria.
- The site must be properly prepared according to direction.
- The vegetable plot must be well tended (insect control is described in Chapter 7).
- Each member of the group will be evaluated individually. A group evaluation will also be given.



Lesson
5 - 2

SKILLS

Ability to extend mathematics to a specific measurement problem

Cooperation

Formatting and presentation skills

Knowledge of botany, agriculture (gardening), and climate

Planning

Research skills

VOCABULARY

Environmental quality

Fertilizer

Insecticide

Natural balance

Organic

Pyrethrum

On Tuesday afternoons during April, May, and June, the interns and I have been working with a gardening group at Common Ground, a residence for the formerly homeless located in the Prince George Hotel. This spooky old building was designed by Stanford White. From their roof garden, you can see the plant district just a couple of blocks away. The tenants are planting vegetables. Some tenants are seniors, some are kids aging out of the foster care system, and one is in veterinary college. Alexis, the tenant services coordinator, organized a donation from Home Depot: Douglas fir, peat moss, and cinder blocks. Gardeners helped unload the material and haul it to the roof. The interns and I also brought wood and compost. Lorenzo brought tomato, collard, and okra seedlings raised at the Kingsborough Psychiatric Facility greenhouse. We made more containers than we planned. Fir is a hard-softwood that weathers as well as cedar and is much less expensive. If steel hadn't been invented, it would probably be the most important material for building in the world.

When people engage in unaccustomed activities such as gardening, there is sometimes awkwardness and tension. That may be because we become "ourselves" when we cannot fall back on our repertoire. Some of the gardeners have planted vegetables before, but planting the roof garden is this group's first community gardening effort. Groups can manage things that individuals can't do on their own—not just simple stuff like lifting and building, but also complex stuff like working with other people. There are some arguments. There is never any development without arguments. Janet says that the only arguing that is worthwhile is arguing with yourself over whether or not to argue with someone. Meanwhile, the tomatoes are ripening and the okra is getting big.

Anna's plot is surrounded by many smaller pots of annuals, roses, and even a *Salix contorta* that she raised from cuttings. It looks like her plot is about to take over the garden. While we are working, I notice one of the interns talking fervently on my wireless phone. When she stops talking, she can barely contain her anger and she is crying. She is living at an in-patient program now. It is very different from the stately Prince George Hotel. Her weekend privileges have been taken away. Her son is in town. She has been doing a lot of gardening at her program to try to gain the necessary volunteer time to get back her privileges. The director told her that only part of it would count.

There are more and more places like Common Ground but it is still very difficult to find space in them.

Fig. 1. Left: Garden guru Anna Tyshko looks over the newest batch of transplants. Tomato, zucchini, and chives await their planting. Tenants who join the garden club each get their own garden plot and are responsible for its upkeep and care. Right: Janet tends her broccoli.

As each new gardener begins to enter into partnership with nature, it is important that they understand the factors influencing the quality of their own environment and how they may of their own volition modify this environment for a safer, healthier life. In many cases, the gardeners will be interns or students, but a gardener may be anyone that is working with plants. Our projects range from the Greenhouse at Rikers Island Jail to community gardens, schools, and residences for individuals with disabilities. In order for them to understand and appreciate the quality of their environment, they must have an understanding of how the environment impacts their lives, and how environmental quality is related to health, society, and the natural world. This unit assumes that each person will be planting a garden in a community setting. The plots that an individual is responsible for in the community garden become the laboratory in which questions may be posed to the natural community and answers obtained. By doing so, it is anticipated that each gardener will gain an understanding of the environmental **relationships** necessary to improve the environmental **quality** of their own lives.

The first question is: What are the benefits to the gardener in the actual planting of a garden? The answer to this question depends in large part upon the enthusiasm and diligence of the individual. People who have prepared the soil and seedbeds, sown the seeds, watered, coped with insects and other pests, weeded and harvested their own garden will very quickly and with very little effort grasp a large amount of information concerning environmental quality, and will be able to apply this knowledge to their own lives. In addition, students will benefit from learning to work together effectively in small groups, as well as learning a practical skill that will be with them throughout their lives.

BACKGROUND:

At HSNY we have by design a mixture of students that are old and young, African American, Hispanic, Asian and Caucasian. Many are from at-risk backgrounds, many have disabilities or are struggling with mental health challenges, some have some experience with gardening, but most do not. Many of our students are from urban environments that are impoverished at best. They have been raised in urban surroundings that are neither healthful, nurturing, nor supportive. As a consequence, many of our students believe that they cannot succeed in school and in life and often act out their frustrations with a system that has failed them. One of our goals at HSNY is to foster in these students a sense of accomplishment and to teach them that they can succeed and have a successful career in whatever field they choose, including gardening and other green collar sectors. The community garden is an ideal vehicle through which to bolster the kind of self-confidence that comes of really knowing how to do something and to instill a sense of pride in accomplishing a definite objective. We have found that as interns and other individuals progress with their garden work, they become more confident, and this carries over into many other areas of life. Most people show a real improvement in many life skills areas as they work hands-on in their gardens. Communication, social skills, empathy, critical thinking and cognitive development all soon advance rapidly once a person has really opened himself or herself up to observation of the world around them with its complex interactions and interdependencies.

One of the most important ways of bringing these changes in awareness in our gardeners is through fostering a sense of cooperation. Many of our people that study with HSNY are rather distrustful of people in general and of teachers and even other members of their own group. By working together on a community garden most students come to realize that they can cooperate with other people and that there is much to be gained through cooperation. They learn that they can accomplish much more and do tasks that they could never accomplish individually. While each student has their own duties, tasks and responsibilities, they must work together to clean up the site, rototill, fence the entire garden, plant the flower beds and bring out the hose daily.

Our method of gardening is what is generally termed “organic gardening.” This method emphasizes a natural balance in the garden between soil, plants and humans. (This is a very popular method, and there are over 33,000 references on the Internet.) The production and use of compost is taught, as well as companion planting and the use of natural pesticides. I have used pyrethrum as my only insecticide for years as well as introducing lady bugs and praying mantis to help do this work. And it is amazing what insects may simply be picked off of plants and disposed of. Each of our dozen or so sites has large compost bins which the students maintain and harvest from year to year. We teach students how to actually plant and maintain the garden plots. Many students have never planted a seed or watched one grow. The production of a successful garden is very satisfying and a real confidence-booster for HNSY’s interns and members of partner groups. And it is most importantly a very successful method for making people aware of environmental quality and associated problems.

As a young boy, I had a chance to experience gardening firsthand in Brooklyn NY in the late 50s and the 60s. There wasn’t much change in that area then. My family, which had recently emigrated from Sicily via South America, did not willingly embrace change. Until the 70s, we continued to live a close-knit family life that included summers in the country, and generally using older, labor-intensive techniques for setting up the vegetable gardens where our uncles spent their free time. Later when I worked as a water technician in East Africa during my service as a Peace Corp Volunteer, I came into contact with the real subsistence life of thorough organic and holistic partnership with the land.

If you drive from Nairobi ,Kenya up towards Uganda on the Kampala to Mombasa highway, you pass through country farmed by the Kikuyu. Their beliefs and lifestyle prevent them from using almost all modern farming methods. They use no electricity or the internal combustion engine. They farm with donkeys, milk their cows by hand, and cling stubbornly to a way of life that is very hard to live. They are often called “simple people,” although their lives are anything but simple. They are very outgoing people, and quickly opened up to when I explained that I was there not to show them a new way of working but rather to help them to use the technologies that they had developed over the centuries to improve the quality of their own lives. Then one of their elders spent three full hours answering my questions and explaining their farming methods.

Fig. 2. Crops are still watered almost exclusively by hand in the Rift Valley – home of the Kikuyu.

The Kikuyu are basically organic farmers. They farm some of the most difficult farmland in central Kenya, land that still supports life for the majority of their people. Why? Because, the Kikuyu maintain and improve the land. They use classic methods of crop rotation, weed control by cultivation, and manure their land each year. They do not use pesticides, and yet year after year, if the rains come, they feed themselves and their livestock almost without any store-bought foods except oil and tea. This raises a very basic question. Just how effective are all of these pesticides, anyway? Here in the U.S. in 1945, when pesticide use was minimal, only 3.5% of the corn crop was lost to insect predation. In 1990, there was a 12% loss of the corn crop to insects. This does not make it sound like the extensive use of pesticides is all that effective (Pimentel and Pimentel, 1979; see also Wade et al, 1994, pg. 297).

METHOD OF APPROACH:

Organic gardening (OG) is a system of gardening that depends upon the use of only natural fertilizers, natural insecticides, and companion planting to maintain the health of a garden. Any method that teaches environmental quality should be simple and demonstrate a minimum of man-made additives to the natural system being studied. (I am well aware that a garden is not strictly-speaking a natural system and actually does not come anywhere near being so, but it is a system that may be manipulated and studied by high school students with some assurance of success.) The OG movement is rooted historically in the type of agriculture that was practiced in this country and in Europe in the eighteenth and nineteenth centuries.

Method is simple. What exactly is involved in OG? Plants are planted as seeds or set out as seedlings just as in any garden. However, the plants are aided in their growth only with natural products. No man-made chemical insecticides, fungicides, herbicides, rodenticides, or fertilizers are used. Pest problems are solved in a number of ways, none of which involve chemicals that are foreign to nature. The simplicity of this method makes it inexpensive, low-tech, and time-intensive.

What is involved? For the students and/or teacher just starting organic gardening, I have prepared some lesson plans that should help students understand much more about soils and plant growth.

Garden Curriculum
A science and horticulture curriculum can be based entirely on a small annual vegetable garden. The following is one example of an integrated science education, life skill, and vocational work curriculum:
Soil Preparation: What is good soil? What is pH? How to test your soil
Composting: Decomposition and nutrient recycling
Seed germination: Reproduction and plant growth
Plant growth: (photosynthesis and transpiration)
Thinning: Competition and ecology
Weeding: Invasive plants and their control
Watering: Evapo-transpiration and the water cycle
Pests: Natural control (IPM); Predator-prey relationships in the garden
Harvest: Plant reproduction and fruit production
Recipes: Nutrition and its effect on health

Exercise
5 - 1

SEED GERMINATION AND GROWTH

This exercise teaches the student a great deal about how a plant grows and is an extremely easy experiment to set up and successfully complete during regular seed starting (see Chapter 7).

Materials: (per pupil)

- 6 containers: small paper cups (4 oz) or 1/2 egg carton
- 6 cabbage seeds, any type (may be any cabbage relatives, such as broccoli, cauliflower, Brussels sprouts, Chinese cabbage, turnips, etc.). Radish is not recommended for this exercise.
- 6 glass dishes with covers, with wet cotton and black construction paper on the bottom. Plastic Petrie dishes work well if deep enough.
- Soil obtained from teacher. Also obtain 2 radish seeds.

Procedure for each student

1. Label each container with your name or initials. Punch a hole in the bottom of each container with a pencil.
2. Put soil in your cups or egg carton sections until 3/4 full.
3. Place one seed in each cup or compartment of the egg carton. Push the seed down into the soil 1/4 inch and just cover it with soil.
4. Water the soil. Dampen it but do not get it too wet. Excess water will drain from the hole you punched in the bottom of the container.
5. Place your cups of planted seeds on the table under the lights. The lights are set on a fourteen-hour time cycle by an automatic timer.
6. Make daily observations of your container. When you see the plant emerging above ground, make daily pencil sketches of the plant and measure its height. Your initial measurements should be in millimeters, later in centimeters.
7. Graph the height of the plant over a two-week period of time. How is the growth rate related to the size of the plant?

Procedure for the entire group

1. Work in groups of fours or fives. Obtain a dish prepared by your teacher with black construction paper on the bottom.
2. Place a total of ten radish seeds in the dish, evenly spaced. Place the dish in a dark environment (a drawer works well).
3. Observe your dish daily. Keep a journal. Without opening the dish if possible, observe what happens as the radish seeds germinate. Try to measure the length of the plant each day. Make a sketch.
4. Research what you have seen. What is the white material around the roots? What are the various parts of the emerging plant named?

Lesson
5 - 1

Exercise 1

SKILLS

Individual responsibility

Indoor seed Planting

Maintaining seedlings

Observation

Recording

Working as a member of a group

VOCABULARY

Centimeters

Germinate

Graph

Millimeters

Observations

BASIC ORGANIC GARDENING

What is involved? The following steps are the basic procedure that one follows when starting a community garden. Again, refer to Appendix Three for a complete bibliography of materials that will help get you started.

1. Selecting the site for the garden. The site must be within traveling distance of the school. Either the students must walk to the site or be able to get there by bus or other means of transportation. Many cities and towns now have organizations of community gardens. They are usually more than willing to help a school find and set up a garden site. The site must be secure and have water available.

2. Cleaning the site. If the students can organize themselves into a clean-up crew, the site can usually be cleaned up with no trouble. Students must be extremely careful when cleaning up. Each student must wear sturdy, thick-soled shoes and heavy gloves. The site may have broken glass, nails, scrap metal, and discarded hypodermic needles. I cannot stress enough the need for proper protective clothing and common sense. There need to be some parent volunteers who can haul trash away in a truck. When the students are cleaning up the site, they must be aware of any potential hazardous waste that may have contaminated the soil (such as containers of paint, lead paint or chips, oil or anti-freeze). Any bare spots must be noted.

3. Planning and Planting the garden (see below). Since not all seeds and plants are placed in the garden at the same time, it is a good idea to plan out the garden and have a calendar of planting dates. Students also need to know how deep and how far apart to plant each variety of vegetables.

4. Weeding and Maintenance (pest control and water). Each student needs to learn to weed their garden and water if necessary. If there are many insects, the use of rotenone and pyrethrin is allowable. Unfortunately, by the time that the plants are up and doing well, many schools are letting out for the summer.

After measuring and plotting the garden beds with graph paper and pencil. The design is transferred to the space using stakes and string. Rikers Island 2001.

The same students are preparing pathways between the beds wide enough for a wheel barrow.

Paths almost finished beds ready for planting

I have been fortunate in finding students who were eager to continue their gardens over the summer. The summer work must be on a volunteer basis.

5. Harvesting. Students may of course harvest their gardens any time during the summer. Most of the harvesting will be the next fall. This can be done in a separate class or with the same students, depending upon circumstances.

6. Preparing for next year. This involves work on the garden in the fall for the coming spring. It might include sowing winter rye, planting spinach, and clearing the garden of old vegetation that may harbor pests.

It would be impossible for me to write all that is needed in order for one to produce a successful garden. That is a separate book. (But see the section entitled BASIC GARDEN PLANNING below.) There are many good basic gardening books that will guide both student and teacher through the joys and trials of organic gardening. Rodale's *All New Encyclopedia of Organic Gardening* (Bradley and Ellis, 1992) is excellent. I have included a number of very good books on organic gardening in a separate bibliography (see Appendix Three). However, some specific suggestions here on seed selection and planting are in order.

At the 607 Seniors' Residence of The Hunts Point Multi Service Center, HSNY interns work with residents to prepare the soil

Before planting anything, set out all your seedlings following the spacing guidelines that you've already researched.

BASIC GARDEN PLANNING:

Gardens are mainly a systematic way of raising particular plants so that each plant grows to its optimum in the time frame of one garden season. There are some basic suggestions that may be followed to produce a respectable garden with very little effort.

The garden plan at the Seniors' Center allowed for an early harvest of leafy greens and a late harvest of zucchini, tomatoes, pepper and eggplant. Collards were harvested throughout the season as were beans. This 2000 sq. ft. garden can feed 30 people at 1meal per day during the harvest.

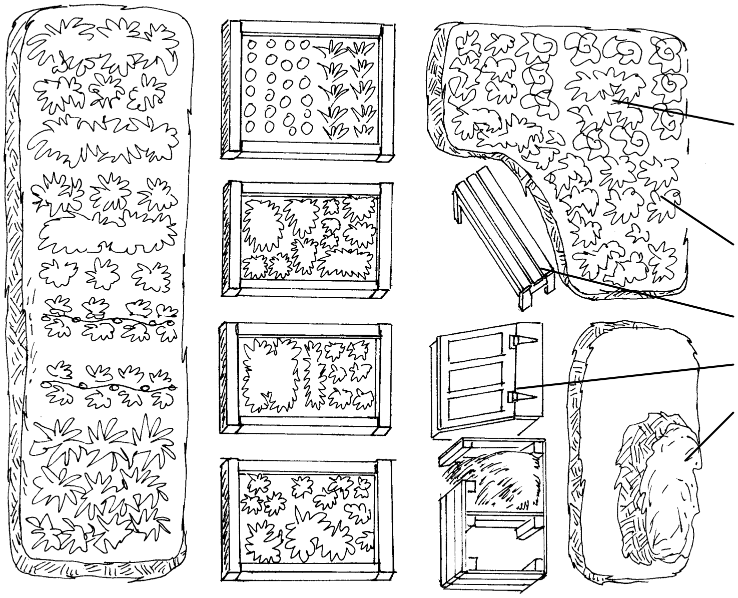


Fig.3. Laying out your vegetable garden

If you enter a store that sells seeds, you may be overwhelmed by the number of varieties of vegetables offered for sale. If you are shopping in a supermarket, you are on your own, and can only be guided by the label information on the packets. But in a real seed store, you should be able to ask which varieties are dependable, relatively trouble-free, and have a good track record. While seeds for everything are on the shelves, you must be aware that some types of vegetables do much better in certain climates. For example, collard greens are southern while kale is northern. Okra does not do well in the north. Many varieties of vegetables have too long a growing season to be usable in the north.

I have included a list of the seeds and plants that we are currently using in our program at HSNY (Table I). I have also included a sample lay-out of a garden plot to show how the seeds and plants might fit together as a whole. One of the early student assignments is the construction of a master plan for their garden plot. You might very well ask how large the individual plots are to be able to plant so many different kinds of vegetables. Our plots are all 12’ x 15’. The dimensions of the plots vary from year to year, depending upon the number of students enrolled in the course. The answer to why so many kinds of plants is that not all students plant every vegetable or flower. One student was almost rude when I suggested that he plant beets. Another told me that she was allergic to eggplant and did not want it in her garden. Most students try most of the vegetables, but very few try them all.

Table 1. Seeds and Plants used at Redhook Senior Center, Spring 2007

SEEDS		NATURAL COMPANION FOR PEST CONTROL	
Radish	**Turnips**	**Tomatoes**	**Marigolds**
Kale	**Chinese cabbage**	**Green Bell Peppers**	**Basil**
Peas	**Snap Peas**	**Egg plant**	**Oregano**
Green beans	**Yellow wax beans**	**Cabbage**	**Onions**
Beets	**Cucumbers**	**Parsley**	**Lemon Balm**
Summer squash	**Winter squash**	**Sage**	**Alyssum**
Pumpkins	**Sweet Corn**	**Ageratum**	**Salvia**
Lettuce	**Romaine**	**Portulaca**	**Petunias**

Exercise

5 - 2

Heirloom varieties are generally more resistant than cultivars. This exercise is helpful in designing a low-maintenance garden. Talk to gardeners that have been planting gardens in your area.

Materials:

- Zone map
- Catalogs and gardening books.
- Notebook, pencils, erasers

Procedure for all students:

1. Look for heirloom varieties that are found in your climate:

- tomatoes
- peppers
- potatoes
- leafy greens
- salad greens
- annuals & perennials (companion plants)

2. Note down their names in your notebook

"Three Sisters" Curriculum

The Three Sisters is a Native American planting scheme that integrates beans, squash, and corn in a mutually dependent gardening system. It works like this:

The bean plants wrap their way around the corn using the sturdy corn stalks as support. The vine or pole bean plant provides the corn with nitrogen for the next growing season when the spent leaves are mulched into the soil. The squash vine wraps around the base of the corn, creating a dense mat that represses competing weeds. The vine also creates a humid micro-climate that helps retain moisture at the soil surface. The tough spines help repel predators like raccoons. The importance of this elegant system was not lost on the Iroquois Indians, who used the crops as a dietary and nutritious food staple. The Three Sisters also feature in their tribe's creation story.

Instructors can use this system as a lesson plan that introduces concepts such as nitrogen recycling, mutually beneficial plant interactions, micro-climate, plant architecture and ethnobotany. It also demonstrates ways to maximize crop production in a low maintenance, energy-efficient system sensitive to the surrounding environment.

Lesson
5 - 2

Exercise 2

SKILLS

Knowledge of planting zones

Research

VOCABULARY

Annual

Heirloom

Perennial

Fig. 4. The 3 Sisters. Choose varieties that are compatible: sturdy corn to support the beans and squash with lush leaves to shade the ground around the plants, and vine beans to climb.

Exercise
5 - 3

CALCULATING SEED AND SPACE REQUIREMENTS

This lesson helps students visualize how to plan their garden as a group to feed the maximum number of people. The example given here is for a garden planted entirely with seed; you may have to consider a percent of these, total if you plan to use seedlings in your garden as well as seeds.

Materials

- Journals, pencils and erasers, calculator

Procedure for all students

1. By pacing off the garden or from your composite designs, calculate the total square footage of your vegetable garden (length in feet x width in feet = area in square feet). Example: if your garden measures 100 feet by 35 feet, then the area of your garden is 100 x 35 = 3500
2. Table 2 gives the garden area necessary to grow these popular crops in quantities sufficient to feed 100 people each day during the harvest. The total area in square feet is just over 7000 square feet.
3. Using the result of the calculation of your garden area in square feet obtained in procedure 1 (the example given is 3500 square feet) as a factor, calculate the number of people that your garden will feed each day during the harvest. To do this you will need to:
4. Divide the area of your garden by the area of the garden in Table 2. Example: if your garden measures 3500 square feet then 3500 / 7000 = decimal value .5.
5. To obtain the number of people that can be fed by a garden with an area of 3500 square feet (the area in square feet given in the example in procedure 1) multiply the number 100 (the population being fed in Table 2) by the decimal value of the product of your calculation. Example 100 x .5 = 50
6. Multiply the necessary areas in square feet and the seed quantities given in Table 2 by the decimal value obtained in step 4 to calculate the areas in square feet and seed needed to plant your own garden. Example: for beet seed 8 oz /x .5 = 4 oz.; for area in square feet needed to grow beets 1800 x .5 = 900
7. In order to distribute your production, divide the area in square feet by the number of individual plots. Using the example developed in steps 1 through 6 for a garden group with 7 individual garden plots. That would be 3500 Square feet / 7 = 500 square feet per individual garden plot.
8. Divide the results per crop obtained in step 6 by the number of individual garden plots to determine the allotment of seed and space for each individual plot. Using the example in step 6 for seed 4 oz / 7 = .57 oz.; for square feet area 900 / 7 = 128 square feet.
9. Distribute crops by consensus equally among individual gardeners.

Lesson
5 - 3

Exercise 3

SKILLS

Decimal multiplication

Division

Multiplication

Table 2. Fresh Meals for 100 People

Crop	Seeds/Space
Bush Beans	3-5 lbs/1,500 sq. ft.
Pole Beans	4-6 lbs/1,500 sq. ft.
Beets	8 oz./1,800 sq. ft.
Broccoli	360/1,440 sq. ft.
Cabbage	200/800 sq. ft.

Note: The square footage includes walkway space for each row. The seed amounts are high to account for thinning and insect problems. The chart is based on harvesting enough food for each day to feed the specified number. It also allows for field damage, kitchen wastes, and the relative popularity of the vegetables. Remember that you will also have to calculate the percent of your garden planted in seed and planted with seedlings.

Table. 3. Planting Calendar

January
SOW
None

PLANT
None

HARVEST
Brussels Sprouts
Winter Radish

SPECIAL CARE
Start sprouts on seed potatoes
Force Rhubarb

PLANT
None

HARVEST
Bay
Rosemary
Parsley

SPECIAL CARE
Prepare bed for strawberries

February
SOW
Brussels Sprouts (frost protect)
Early Carrots (frost protect)
Maincrop Onion seed (protect)
Summer Lettuce (protect)
First Early Peas (protect)
Summer Radishes (protect)
"Sprout" potatoes

PLANT
Maincrop Onion sets

HARVEST
Brussels Sprouts

SPECIAL CARE
Prepare bed for carrots

PLANT
None

HARVEST
Bay
Rosemary

SPECIAL CARE
Prepare bed for strawberries
Prune autumn fruiting raspberries

March
Vegetables
Fruit, Herbs

SOW
Broad Beans
French Beans (cloche protect)
Broccoli (early sprouting)
Brussels Sprouts
Cabbage
Early Carrots
Summer Lettuce
Maincrop Onion seed
Spring Onions
Peas (early)
Summer Radish

PLANT
Maincrop Onion sets
New potatoes
Maincrop potatoes (15th on)

HARVEST
Broccoli (early sprouting)
Brussels sprouts (1st half of month)
Spring-maturing lettuce

SPECIAL CARE
Dig beds for tomatoes, runner beans, French beans and sweet corn.

PLANT
Final chance for bare-rooted apples, cherries, pears and plums.
Strawberries (end month)

Bay
Chives (indoors)
Marjoram/oregano (indoors)
Parsley (indoors)
Rosemary
Sage seed indoors
Tarragon (late)
Thyme

HARVEST
None

SPECIAL CARE
Protect peaches from frost

April
Vegetables
Fruit, Herbs

SOW
Beetroot
Broad Beans
Broccoli (early sprouting) end month
Calabrese (early) - protect
French Beans (end of month)
Runner Beans (protect)
Brussels Sprouts
Cabbage
Carrots (early)
Carrots (maincrop) mid-month
Summer Lettuce
Maincrop Onion seed
Spring Onions
Peas (early and maincrop)
Summer Radish
Sweet corn (protect)
Tomatoes (indoor and cloche)

PLANT
Onion sets
New potatoes
Maincrop potatoes

HARVEST
Broccoli (late sprouting)
Spring maturing lettuce
Summer Radish (cloche protected)
Forced Rhubarb

SPECIAL CARE
Spray Peas with derris

PLANT
Strawberries

Basil
Bay
Chives (outdoors)
Dill
Marjoram/oregano (outdoors)
Mint
Rosemary
Sage seed outdoors
Sage rooted plants outdoors
Tarragon
Thyme (by root division)

HARVEST
Tarragon
Rosemary
Sage

SPECIAL CARE
Protect peaches from frost
Spring prune peach trees

May
Vegetables
Fruit, Herbs

SOW
Beetroot
Broad Beans (start of month)
Broccoli (late sprouting)
Calabrese (start of month)
French Beans (start of month)
Runner Beans
Cabbage
Carrots (maincrop)
Lettuce
Peas
Summer Radish
Sweet Corn (end of month)
Tomatoes (direct in soil)

PLANT

Maincrop potatoes

HARVEST
Peas sown under cloches
Summer Radish
Rhubarb

SPECIAL CARE
Earth up new potatoes
Earth up maincrop potatoes
Transplant Brussels sprouts
Transplant Tomatoes

PLANT
Strawberries (start of month)

HARVEST
Bay
Chives
Rosemary
Sage
Tarragon
Thyme

SPECIAL CARE
None

June
Vegetables
Fruit, Herbs

SOW
Beetroot
Broad Beans (start of month)
Broccoli (late sprouting)
Calabrese (start of month)
French Beans (start of month)
Runner Beans
Cabbage
Carrots (maincrop)
Lettuce
Peas
Summer Radish
Sweet Corn (end of month)
Tomatoes (direct in soil)

PLANT
Maincrop potatoes

HARVEST
Peas sown under cloches
Summer Radish
Rhubarb

SPECIAL CARE
Earth up new potatoes
Earth up maincrop potatoes
Transplant Brussels sprouts
Transplant Tomatoes

PLANT
Strawberries (start of month)

HARVEST
Bay
Chives
Rosemary
Sage
Tarragon
Thyme

SPECIAL CARE
None

July
Vegetables
Fruit, Herbs

SOW
Carrots (quick maturing)
Lettuce (1st half of month)
Summer Radish
Winter Radish (end of month)

PLANT
None

HARVEST
Beetroot
Carrots
Lettuce
Peas
French Beans
Summer Radish
Spring Onions
Japanese Onions
Rhubarb

New Potatoes

SPECIAL CARE
Prepare for Japanese onion seed

PLANT
None

HARVEST
Basil
Bay
Chives
Dill
Mint
Marjoram / oregano
Parsley
Rosemary
Sage
Tarragon
Thyme
Gooseberries

SPECIAL CARE
None

August

Vegetables
Fruit, Herbs

SOW
Japanese Onion seed
Summer Radish
Winter Radish (end of month)

PLANT
None

HARVEST
Beetroot

Calabrese (Italian broccoli)
Carrots
French Beans
Runner Beans
Lettuce
Spring Onions
Maincrop Onions (from sets)
Peas
Potatoes (maincrop)
Summer Radish
Sweet corn
Tomatoes

SPECIAL CARE
Prepare ground for new rhubarb

PLANT
None

HARVEST
Basil
Bay
Chives
Dill
Garlic
Mint
Marjoram / oregano
Parsley
Rosemary
Sage
Tarragon
Thyme
Blackberries

Blackcurrants (2nd half of month)
Currants (last part of month)
Loganberries
Raspberries
Plums
Strawberries

SPECIAL CARE
Prepare ground for new currants, blackberries, peach tree, apricot tree, gooseberry bush

September

Vegetables
Fruit, Herbs

SOW
Spring-maturing lettuce
Summer Radish
Winter Radish (end of month)

PLANT
None

HARVEST
Beetroot
Calabrese (Italian broccoli)
Carrots
French beans
Runner Beans
Lettuce
Onions (from seed and sets)

Spring onions
Peas
Potatoes (maincrop)
Summer Radish
Sweet corn
Tomatoes

SPECIAL CARE
None

PLANT
None

HARVEST
Basil
Bay
Chives
Mint
Marjoram / oregano
Parsley
Rosemary
Sage
Tarragon
Thyme
Apples
Apricots
Blackcurrants
Blackberries
Currants
Loganberries (1st half of month)
Peaches (1st half of month)
Pears
Plums

SPECIAL CARE
Prepare for new raspberries
Prepare for new plum tree
Prepare for new loganberries
Prepare for new pears
Prepare for new apple tree
Prepare for new blackcurrants

October

Vegetables
Fruit, Herbs

SOW
Spring-maturing lettuce

PLANT
Rhubarb

HARVEST
Beetroot (1st half of month)
Brussels Sprouts
Calabrese (Italian broccoli)
Carrots (1st half of month)
French Beans (1st half of month)
Lettuce (1st half of month)
Onions (seeds and sets)
Peas (1st half of month)
Potatoes (maincrop)
Radishes (1st half of month)
Sweet corn (1st half of month)
Tomatoes (1st half of month)

SPECIAL CARE
None

PLANT
Apricot-L
Blackberries
Chives (division)
Currants (middle of month on)
Garlic
Peach
Raspberries
Gooseberries
Plum

HARVEST
Basil
Bay
Chives
Mint
Marjoram / 0regano
Parsley
Rosemary
Sage
Tarragon
Thyme

Apples
Currants
Peach (1st week only)
Plums (1st week only)

SPECIAL CARE
Prune Bay Tree

November

Vegetables
Fruit, Herbs

SOW
None

PLANT
None

HARVEST
Brussels Sprouts
Onions (first half of month)
Winter radish

SPECIAL CARE
Prepare bed for New Potatoes
Prepare bed for beetroot
Prepare bed for Rhubarb

PLANT
Apple Trees
Blackcurrants
Currants (1st half of month)
Gooseberries
Loganberries
Pear tree
Plum tree

HARVEST
Marjoram / 0regano
Parsley
Rosemary
Sage
Thyme
Apples

SPECIAL CARE
None

December

SOW IN DECEMBER
None

PLANT IN DECEMBER
Rhubarb

HARVEST DECEMBER
Brussels Sprouts
Winter Radish

SPECIAL CARE
Prepare beds for onions.
Brussels Sprouts
Summer Lettuce
Maincrop Potatoes
Peas
Onions

Order vegetable seed catalogues

PLANT IN DECEMBER
Apple Trees

HARVEST DECEMBER
Rosemary
Parsley

SPECIAL CARE
Order herb and fruit catalogues

Exercise
5 - 4

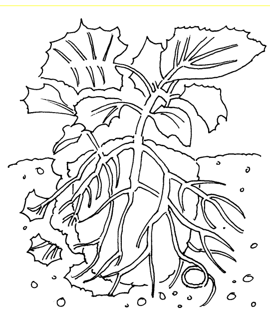
CREATING YOUR VEGETABLE GARDEN

Materials
- Graph paper, pencils, eraser
- Notebook
- Garden planning basics information
- Planting calendar table 3.
- List of vegetables for the garden
- Plant spacing information determined from calculations
- Gardening tools
- Seedlings started in exercise 5-2 -1
- Stakes, string, tape measure

Procedure for all Students
1. Clean up site separating organic matter suitable for composting from non-compostable.
2. Amend soil (refer to Chapter 4: Soil Amendment)
3. Synthesize all garden plans to assure the greatest variety and most productive crop rotation.
4. Use calculations from exercise 5-2-3 to arrive at proper allocation and distribution of crops among individual plots.

Procedure for each Students
1. Using journals, make out a planting calendar using Table 4.
2. Using graph paper, plan the design of the garden plot
3. Lay out all plots so that access is easy from all sides. Lay out paths so that wheelbarrows can easily pass.
4. Measure and stake out plot (refer Chapter 6 for implementation).
5. Set out seedlings to harden off during the day (refer to chapter 12 for information about hardening off seedlings of seeds germinated indoors.
6. Sow large seeds directly according to spacing information on seed packet and from results of exercise 5-2-3 and garden design.
7 Plant seedlings according to garden design, space requirements, and proper planting technique as shown in Figure 4.

Fig. 4. Proper planting technique



Incorrectly planted note air spaces

When a plant is correctly planted the soil should be packed around roots

Lesson
5 - 4

Exercise 4

SKILLS

Long-term planning

Measuring

Planting seedlings

Synthesis of information

Time management

VOCABULARY

Allocation

Air pocket

Distribution

Hardening-off plant

Seedling

Sow

WORKING AS A GROUP

No gardener can plant everything. But the way in which we ask them to lay out some areas in their plots for the natural pest control experiment partly dictates how the garden will shape up. I used to award a prize to the student who designs the best garden, but I no longer do that. The best award of all is the produce from a well-designed garden, which is the sum of all the individual plots. If you examine a typical garden layout (Fig. 3), you will see that I have not included all of the plants in one plot.

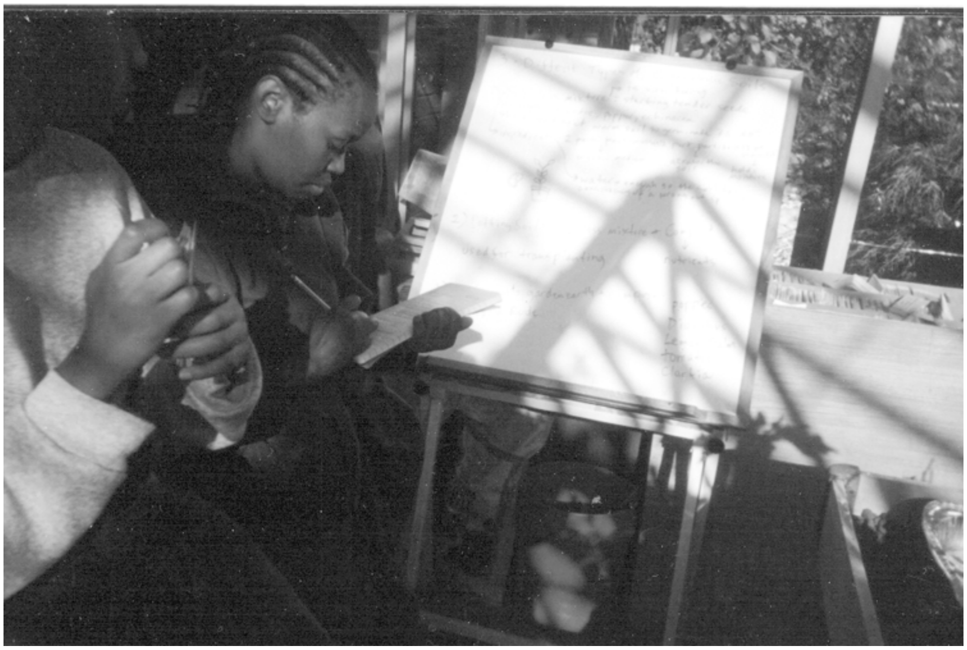


Fig. 5. Students at HSNY's GreenHouse program at Rikers Island work together to record results of their seed starting lessons.

THE GARDEN AT FRUITION:

Just as plants need to be planted in a time sequence, they are ready to harvest at different times. The first plants normally ready are the radishes (for which I usually give a prize for the largest). These are followed some time later by the peas, then beans and lettuce and parsley. Later still, during the summer, cucumbers, tomatoes, peppers, corn, etc. are ripe. There are also plants that ripen in the fall, such as winter squash and pumpkins. Some plants such as kale may be harvested up until frost.

The problem is that no one ever seems to say much about how you harvest the produce. There are some suggestions in the organic gardening books (see Appendix 3) but no really good and complete instructions. This leaves the gardeners on their own. They must use their own judgment.

The best solution is to have some kind of organized summer activity that will help the students to tend and harvest their own gardens. If this is not possible, students may still work on their gardens on a volunteer basis and on their own. But there must be some thought given to security. Is the garden site a place where students may safely go alone? If it is not, then a group activity is needed.

Fall plants may be harvested either by the original students or by a subsequent class given in the fall. Classes that are working in the fall can prepare the site for winter and harvest the fall produce. We are trying a program this fall where all of the produce harvested will be weighed and measured. The class will then calculate yields of various plants.

ENVIRONMENTAL QUALITY AND AWARENESS:

We have learned some bitter lessons concerning pesticides over the last fifty years. Our scientists have found that chlorinated hydrocarbons, PCBs and dioxins all have persisted in the environment long after their manufacture and use was banned (Carson, 1962; Colborn *et al*, 1996; Tschirley, 1986). Yet we continue to use an enormous array of over 10,000 poisonous chemical formulations as pesticides to this day. And more of these toxic compounds are being approved for use each year (Wargo, 1996).We have learned that these compounds are toxic in large doses, and that many of them are carcinogenic at much lower, sub-toxic levels. Recently we have begun to realize that many of these persistent chemicals also may act as hormone disruptors at low levels, causing abnormal development especially of the nervous, reproductive and immune systems (Colborn *et al*, 1996).

The fact is that we **all** have pesticide residues in our bodies, particularly in fatty tissue. There is virtually nothing that we eat that is not contaminated with these residues. The rational for permitting these toxins in our foods is that they are present at levels that are tolerated by our bodies. Thus there are tolerance levels assigned to almost all residues in foods. These are levels that have been calculated as “safe” by the FDA and EPA. Unfortunately they do not seem to have taken into account accumulation of these toxins in fatty tissues or the hormonal disruptions that may occur at very low levels (Wargo, 1996; Colborn *et al*, 1996).

If we examine Figure 1 again, we can obtain a better sense of the methods by which many of these contaminants reach our food. Metals may be present in the soil naturally, or they may have been introduced from contaminated water, in pesticides or as air-borne particulates. Water may be contaminated from run-off, from inadequate sewage treatment and from absorbing particulates from the atmosphere. Some atmospheric contaminants are present naturally, such as turpenes and ozone, while others are the products of man, such as acid rain. Many organic compounds in the soil are deliberately introduced as pesticides, while others come from the atmosphere and are deposited by rain.

Environmental textbooks often show accumulation of contaminants in the food chain (Miller, 1990), but they seldom seem to show what happens in cultivated ground. And this is extremely important because it is from cultivated fields that we obtain almost all of our foods. These same contaminants are present both in vegetables and fruits, and also in meats. All of our commonly eaten meat animals, including cattle, swine, sheep and poultry, derive all of their food materials from plants.

There are a great number of pesticides used on crops, and they are often used frequently. Some crops are sprayed up to twenty times a growing season. Why? For two reasons. First of all, they are sprayed to minimize loss to insects and other pests. Secondly, they are sprayed for cosmetic reasons. Each plant crop has cosmetic criteria, including color, surface appearance, and blemishes. Many fungicides are sprayed to minimize surface blemishes. But these blemishes have nothing to do with the wholesomeness of the fruit or vegetable, only with the surface appearance. So why use them? Because all produce is graded, and the producer is paid based on the grade of his produce. Have you ever peeled a nice orange, only to find that the color comes off on your fingers? A cosmetic dye was used on that orange, and it probably was a carcinogenic aniline dye. How much got into the part that you ate?

One other serious problem that we have not discussed is what happens to these toxic residues once they are in garden produce. These residues are taken up by the plant along with water and minerals from the soil. As such, they are incorporated into the cells and tissues of the plant. They cannot be washed off like some air-borne residues. Thus, we ingest these residues directly when we eat plants and secondarily when we eat animals (Wargo, 1996). And our bodies must deal with these residues as best they can. We have already seen that these residues may be both carcinogenic and act as hormone disruptors (Wargo, 1996; Colborn *et al*, 1996). Unfortunately, even with the knowledge that we have, it is very difficult to get the government to act to eliminate the use of the pesticides in question.

In 1962, Rachel Carson alerted the country and the world to the dangers of chlorinated hydrocarbons, especially DDT. Wargo and Colborn raised the same cry in 1996 with regard to pesticide residues of all types, especially their accumulation in children. But to this date, the government has not responded in any decisive manner. Part of the problem is the fact that responsibilities for monitoring and regulating pesticides fall under the jurisdiction of three separate federal agencies—the USDA, the EPA and the FDA. These agencies use different sampling procedures, different analytical procedures, and different statistical methods. The end result is that it is very difficult to obtain action from any of these agencies.

Another problem is one of human nature. It is very difficult for any of these federal agencies to admit that they made a mistake. Instead of admitting that their knowledge was imperfect ten years ago, they mostly hold to their original position regarding any pesticide. If they approved it, it must be OK to use it. (Wargo, 1996). A classic example is the mercury poisoning at Minimata, Japan. These victims are still, to this day trying to get the Japanese government to admit that it was negligent (Smith and Smith, 1975). And it is virtually impossible to get a corporation to admit to culpability in these types of cases (Harr, 1995).

While the United States prohibits the sale and use of a number of pesticides, we are often the world’s largest producer of a prohibited pesticide (DDT is a good example). We export tons of these pesticides, mostly to third-world countries. And we get these pesticides back in imported produce in what is called the “Boomerang Effect.” Each year we import more and more fresh produce from abroad. The cantaloupe you buy in the supermarket in February were not produced in this country, but probably came from Ecuador, Costa Rica, or Mexico. And in these countries, they use pesticides that are prohibited in the United States, and some that have never even been registered in this country. So this is another way in which the residue level in our bodies is increased.

Is there any way by which the pesticide levels in our bodies can be lowered or at least held at present levels? Yes, there is. People can raise more of their own food, and do it pesticide-free. I have attempted to show how growing your own crops in an organic garden can minimize the amount of pesticide residue that is entering your body. You may not be able to do much about those residues found in produce in the supermarkets, but you can cut down on residue intake if you use foods raised in your own garden. You may also buy produce raised pesticide-free, so-called “organic produce.” Some states now have requirements for organic certification by producers, and “certified organically-grown” seals on the resulting produce (Armstrong, 1983; Bergin and Grandon, 1984).

Finally, let me say that most of the students I have taught in our program have become very enthusiastic about gardening the organic way. And most importantly, they have gained self-respect and pride in being able to complete a garden of their own. For these reasons and for the health of our children, I urge you to try this unit. It is very rewarding both for students and teachers.

Bibliography

French, Allen, 1870-1946., *The book of vegetables and garden herbs; a practical handbook and planting table for the vegetable gardener,* by Allen French., New York London The Macmillan company, 1907

Cutler, Karan Davis., *Burpee-- the complete vegetable & herb gardener : a guide to growing your garden organically* / by Karan Davis Cutler ; photography by David Cavagna. , New York : Macmillan USA. , 1997

Cunningham, Sally Jean., *Great garden companions : a companion planting system for a beautiful, chemical-free vegetable garden* / Sally Jean Cunningham., Emmaus Pa. : Rodale Press ; [New York] : Distributed in the book trade by St. Martin's Press. , 1998

Rogers, Marc., *Garden way's Growing & saving vegetable seeds* / Marc Rogers ; illustrated by Polly Alexander., Charlotte Vt. : Garden Way Pub., 1978

Gerras, Charles, ed., *300 of the most asked questions about organic gardening, answered by the editors of Organic gardening and farming magazine*. Compiled and edited by Charles Gerras, with Joan Bingham, Joanne Moyer and Irene Somishka. Special editorial assistance by Betty Frederick. , Emmaus Pa. Rodale Press. , 1972

Garrett, Howard, 1947- , *The dirt doctor's guide to organic gardening : essays on the natural way* / J. Howard Garrett., 1st ed., Austin : University of Texas Press, 1995

Franck, Gertrud., *Companion planting : successful gardening the organic way* / by Gertrud Franck ; translated from the German by Transcript., Wellingborough Northamptonshire England : Thorsons Pub. Group ; New York N.Y. : Distributed by Sterling Pub. Co., 1983

Chapter 6: Pollinator Gardens

Performance Objectives

Students will be able to:

- Select the plants for the pollinator garden using criteria in lesson.
- Plan and plant the pollinator garden site.
- Keep the pollinator garden site weed-free and well-watered.
- Demonstrate knowledge of pollinators and the plants they favor.
- Cite examples of how insects senses differ from human senses.
- Cite examples of co-evolution.
- Cite examples of practical application of pollination.
- Demonstrate knowledge of the mutual adaptations of plant and their insect pollinators.

Assessment will be based on several criteria:

- The site plan must meet all criteria.
- The site must be properly prepared according to direction.
- The pollinator garden must be well planted and tended
- Students must demonstrate a working knowledge of taxonomy
- Students must be able to list relevant pollinators.
- Each member of the group will be evaluated individually. A group evaluation will also be given.

Lesson
6 - 1

SKILLS

Basic biology

Basic entomology

Design and installation skills

Horticultural skills and garden maintenance

Research skills

VOCABULARY

Adaptation

Bees

Butterflies

Co-Evolution

Design

Ecology

Environmental science

Moths

Pollination

Reproductive cycles

Species

Pollinator Gardening

Plants contain an ancient pattern of sexual reproduction. Just as our earth changed radically when photosynthesis began to occur at a rate that oxygenated the atmosphere so that vertebrae could evolve, so life became infinitely more diverse and developed when sexual reproduction became the pattern for all higher life. Plants were pioneers in each of these developments. Plants, though, are immobile or move very little so in order to achieve their desires, they recruited insects as their willing partners. The co-evolution of plants and their insect pollinators is an example of the altruism, beauty, and cooperation of nature. Since so many of the foods that we harvest from plants are seeds or the wrappings that protect them, the reproductive cycles of plants have been intrinsically bound up with the life of humans to the extent that they have determined the rise and fall of civilizations. Civilizations rose as a result of the discovery of plant cultivation. Civilizations have fallen as well due to shortages of seed-based foods. The French Revolution was aggravated by shortages of bread in Paris in 1789.

“Pollination Gardening” is a unit designed to introduce students to the mutual adaptations of flowering plants and their pollinators: honeybees, bumblebees, butterflies, and moths. The lesson focuses on both flowers and insects in the field to see how they have become adapted to one another. One goal of the unit is an understanding of co-evolution—that species are dynamic and changing with respect to each other. Another goal is the understanding that insects have different senses from humans and a third goal is the practical applications of pollination. The unit is best taught in May when there are an abundance of flowering plants outdoors.

Mira que mariposa pasa aqui!

There is something about butterflies. It is summer 2002. There is a lot of routine maintenance to do at the greenhouse at Rikers Island. It is amazing how quickly the weeds grow. There is a small crew. We can scarcely stay ahead of the weeds. There are 2 brothers with us. They know that they will go home soon. The scarcely speak any English, so communication is slow. One is an automobile mechanic, and the other is a construction worker. It is hard for them to become excited about the garden. It is a place to go. It is better than the laundry. They spend a lot of time talking amongst themselves instead of working at the tasks that so urgently need to get done: weed the vegetable garden and water it, feed the rabbits, weed and water the large woodland and native flower gardens, and take care of the butterfly garden. Even tasks for which they only can really do—fixing the small engines of mowers and string trimmers, and mending the broken railings on the gazebo just don’t seem to capture their imagination. Finally, it is the last week before they leave. This is a difficult week for our students anyway. Some feel strangely reluctant to leave, having gotten used to the security and routine of the greenhouse. Others cannot concentrate, having already psychically moved into the complex world of reentry with all of its hopes and terrors. It is such a hot day that it is a struggle just to pick up a shovel.

“Mira que mariposa pasa aqui!”

They are in the big perennial garden talking. Suddenly a huge swallowtail butterfly comes careening right into the bed that they are working in. They stop their conversation and breathlessly watch the butterfly drunk on nectar zig-zag through the bed. For a moment they forget all about what will happen tomorrow. They are obviously excited. This visitor from another world swoops and lands on a flower inches from where they kneel. It draws their eyes with magnetic power matched only by the fragility of its delicate transparency. The deeper they stare into the butterfly’s patterned wings, the more they forget about their own existence. Or rather their existence is merged with that of the butterfly. Suddenly, like a person starting from a dream, he reaches to touch the butterfly. It is too much even for the sated butterfly to allow and it is back in the air with a hop and flutter that sends them chasing after it. They are stopped by the 20-foot-high fence which the swallow tail mounts easily. It really didn’t have to stop at all.

Who are the Pollinators?

It is a warm sunny day in the middle of May and red clover is in bloom in the meadows. A bumblebee moves from flower to flower, reaching deep into each with her proboscis and tongue to suck up the nectar. As she does this, the stamens (male organs of the flower) move up and hit her on the abdomen, dusting her with pollen. On she flies to another clover plant, and this time her abdomen touches the stigma (the top of the female organ) which scrapes off some of her pollen. The bee has unwittingly achieved the plant's aim—cross-pollination—and has filled her own honey-stomach with nectar. She begins to clean her body of pollen grains, working them from the front to the hind legs where they are finally compacted into a hairy container called a pollen basket. Now she flies back to the nest to empty her loads of nectar and pollen.

Bumblebees and red clover are two organisms that are interdependent. The plant, which would become extinct without its pollinator, has developed several features that almost guarantee pollination: attractive petals, sufficient nectar, stamens that release pollen on the underside of the bee, and a stigma that precisely picks up pollen that the bee carries from other red clover flowers. Although each red clover flower contains both male and female sex organs it is self-sterile and depends wholly on pollen from other plants in order to set seeds. The bumblebee, on the other hand, gets all its food from the flowers; the nectar provides carbohydrates and the pollen supplies both protein and fats. A bee will die of starvation in an hour if deprived of these floral foods (Heinrich, 1979).

Maybe you have heard the saying that the power of the British Empire rests (or rested) on its bumblebees. British sailors eat beef, the beef cattle eat clover, and the clover is pollinated by bumblebees. That this saying was not so far-fetched became obvious last century in New Zealand. Settlers from England had brought over red clover to plant as a forage crop, but it never set seeds. Finally, it was realized that there were no native bumblebees in New Zealand to pollinate the clover and in 1880, one hundred English bees were imported. Seed set was no problem afterwards (Meeuse, 1961). Bringing in hives of honeybees (instead of bumblebees) to New Zealand would not have solved the problem of the red clover, however. Honeybees have a tongue that is only about 6 mm long, not long enough to reach the nectar deep inside the red clover, which is available only to bumblebees with a longer tongue. On the other hand, honeybees are more efficient pollinators of white clover, which has a much shorter flower.

Flowering plants (angiosperms) and their pollinators have become adapted to one another over the ages for maximum mutual benefit. This is called CO-EVOLUTION and has been taking place ever since angiosperms first appeared in the fossil record of the Cretaceous period, about 90 million years ago (Percival, 1965). *Hymenoptera* (bees and wasps) had already made their appearance in the Jurassic period, 144 million years ago and the *Lepidoptera* (butterflies and moths) began to evolve in the Tertiary of the Cenozoic era, starting about 60 million years ago.

It is difficult to see the details of the co-evolution of flowering plants and their pollinators from the spotty fossil record, but a lot can be inferred from studies of living organisms.

Of course, Plants are stationary and can reproduce only if their pollen is carried by wind, water, or various animals from one flower to another. There is great competition among the angiosperms to secure visits by pollinators. Many plants have developed flowers with attractive colors and scents. There may or may not be food rewards offered. One orchid, *Ophrys*, mimics a female bee so perfectly that male bees try to mate with it. Unknowingly, they get pollen caught on their bodies (Baker, 1963).

Usually flowers do offer food in the form of nectar and/or pollen in order to attract pollinators. The amounts offered are usually quite tiny so that the pollinators are forced to visit as many flowers as possible.

Insects compete intensely with one another for this available nectar and pollen. Heinrich (1979) reports observing a bumblebee that visited 800 jewelweed flowers in two hours. Often bumblebees work from dawn to dusk, visiting 20 to 40 flowers per minute.

The most efficient pollinators are those that are adapted to certain flowers (such as bumblebees to red clover). If one knows enough about a pollinating animal—whether it has color vision, is nocturnal or diurnal, the length of its tongue, the ability to hover—one can make a very educated guess as to which flowers it might pollinate. Conversely, it is often possible for a biologist to look at a flower and decide from its appearance how it is pollinated, whether by bees, butterflies, moths, birds, bats, flies, wind, or by a combination of methods. Last century, a new orchid, *Angraecum sespuipedale*, with a corolla tube of 30 cm was found in Madagascar. Its pollinator was unknown but Alfred Wallace (of evolution fame) correctly predicted that it would turn out to be a hawkmoth with a proboscis that could reach all the way down to the nectar (Percival, 1965).

It should be emphasized that though many flowers and pollinators are specifically adapted to each other, there are also many flowers that are visited by numerous different insects.

a.

b.

c.

d.

a. A polydamas swallowtail *(Battus polydamas)* sips nectar from a Mexican sunflower (*Tithonia rotundifolia* "Torch").

b. A monarch (*Danaus plexippus*) drinks from scarlet milkweed (*Asclepias curassavica*). Milkweed is a must for any butterfly garden: it's a nectar plant for the adults, and also a host plant for monarch caterpillars.

c. A black swallowtail caterpillar eats parsley.

d. A gulf fritillary caterpillar nibbles on passionvine.

Wind-Pollinated Flowers

Flowers that depend on the wind for pollination are usually very small and plain with single-sex flowers. Because they do not depend on animal pollinators, they do not need to produce nectar or strikingly colored petals. Much of the plant's energy goes into making pollen to compensate for the fact that so few pollen grains actually reach the female flowers. The amount of pollen produced is staggering: a single corn plant may have from 20 to 50 million grains (Rahn, 1975). (Insect-pollinated flowers produce far fewer pollen grains since pollination is a much more certain thing.)

Wind-pollinated flowers have long feathery stigmas that catch the pollen that comes flying through the air and the stamens dangle loosely at the ends of long threads. Often the male flowers are arranged into catkins which move in the wind, freely releasing pollen into the air. Tree flowers that are wind-pollinated often bloom early in the spring before leaves emerge, giving the pollen a better chance to reach the female flowers on other branches or trees. Many trees of colder climates are wind-pollinated such as oak, poplar, birch, elm, walnut, alder, hazel, and conifers. Other common plants include grasses, ragweed, dock, and plantain.

Certain times of year when wind-pollinated trees or grasses are blooming may be a time of tribulation for hay fever sufferers. The abundant pollen from these plants often contains a protein which acts as an allergen when it lands on our mucous membranes. Although it is harmful to us, this protein serves an important function for the plant. Wind-pollinated plants are usually self-incompatible and pollen grains will not germinate if they land on a stigma of the same plant. It is this allergen protein which acts as the inhibitor to self-fertilization (Lewis, 1979).

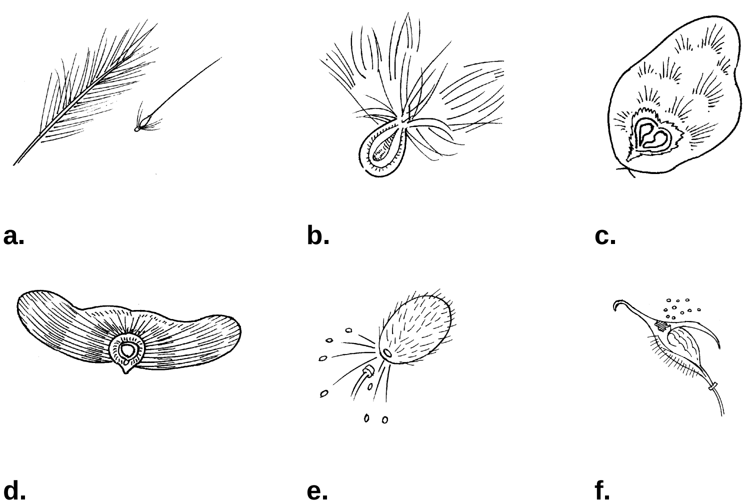


Fig. 10. Windborne seeds. A. Grass; b. Dandelion; c. Tulip tree; d. Sycamore; e. Impatien; f. Unicorn plant

Activities

Flowers were studied in Chapter 3: Understanding Plants. One or two flowers were dissected and the parts are learned. Perhaps this is the right place to go in to the subject of pollination ecology in more depth. This unit will in an attempt to approach it more equally, looking at it from both the viewpoint of the pollinators and the plants. How are various insects adapted to pollinate specific flowers? How have plants adapted to derive maximum benefit from their pollinators? Now that the students have some understanding of floral structure, there will be lessons on pollinating insects. Then there will be a final lab to see whether students can look at the structures of flowers and guess which insects pollinated them. As well as encouraging their powers of observation, this exercise should also develop their powers of reasoning, for they will have to explain their answers.

Floral pollination is best taught in early May, when New York gardens and trees are in full bloom. (Any earlier and the instructor may need to purchase flowers at the florist.) Students should also be encouraged to bring in flowers for the exercises. Insects may be purchased from biological supply companies, but we usually catch then in the field. The library of the Horticultural Society of New York has many beautifully illustrated books on pollinators. These can be photocopied and used to help identify species encountered in the field.

Butterflies and Butterfly Flowers

Butterflies are different from bees in many of their pollinating characteristics. They have a much longer proboscis made of two halves that fit together to form a long hollow tube. This tube is kept coiled up under the head like a watch spring when not in use. Their only food is nectar, unlike honeybees who gather pollen both for themselves and their larvae. Butterfly larvae (caterpillars) subsist wholly on plant foliage.

If nature is drama, then butterflies are principal actors who bring the garden alive in a dynamic and aesthetic manner. Unlike formal gardens with their fragrant roses and flowering hybrids, butterfly gardens are reliant on a jumble of flowering plants that provide nectar for the butterflies all season long, as well as habitat and food for their larvae, the caterpillar. A small flowering plant hovering in the corner of the garden may be considered a weed, but it also might be an important food source for a fritillary, swallowtail, or monarch. Attracting butterflies to the garden, especially in isolated areas like the yard of a prison, demands a greater understanding of what butterflies need to survive and proliferate. What do butterflies eat? Which kind of plants do they lay their eggs on? What do the larvae need for survival in each stage of metamorphosis as they transform into chrysalises and butterflies?

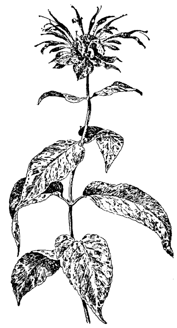
Planning and maintaining the habitat of butterflies brings student horticulturists closer to the natural world and strengthens their understanding of ecology and science. The creation of these gardens helps mitigate the loss of native landscapes and provides vegetative corridors that may ensure the long-term survival of different butterfly species. Not only do butterflies have important roles as pollinators, but they are also early indicators of ecological threats to the environment. Their presence in the garden is an indication of diversity and a healthy, functioning system.

The real-life experience of creating and caring for gardens that attract pollinators like butterflies, moths, and bees makes up a large part of this unit. Each season we will when designing gardens have opportunity to include from the plants discussed in this unit, examples that will provide habitat for pollinators and which in turn will attract them to the garden for the purpose of aiding them in their goal of reproduction. The byproduct of this relationship is the opportunity to observe and study the principal of co-evolution in the garden while having the satisfaction of luring gorgeous butterflies, industrious bees, and mysterious moths into a space which hitherto may not have seen these beautiful and necessary creatures for many years. To do this, students will study design principles, create their own designs, and under your direction, will implement well-thought-out plans that utilize appropriate plants. As students work as partners in the enterprise of co-evolution, they will begin to experience an emotional connection to the cycle of life in the gardens they work in. Every day the lessons of altruism, cooperation, and symmetry will be reinforced as they work among themselves as a group or as individuals, paralleling the ancient relationship that is a cornerstone of evolution and development on earth. The plant gives willingly of its nectar and the bee tirelessly visits plants collecting the minute drops of nectar, performing an invaluable service to the plant as they do so. It is the pleasure principle in miniature. It is almost enough to make you believe that the pleasure principle is the foundation of all cooperation.

Now let’s look at some of the plants that form the local community of pollinators. These plants function in many ways. They may serve as nectar sources for pollinators such as butterflies, or if their goal is to attract bees, then pollen will also be an important food. Some may be host plants for caterpillars or food for both caterpillar and butterfly. To increase the number of butterflies in your garden, increase the number of host plants and nectar sources. Here are just a few.

Fig. 1. Some common butterfly flowers of the United States from zones 4–7.

a.



b.

c.

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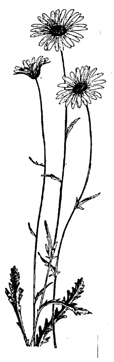

g.

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i.

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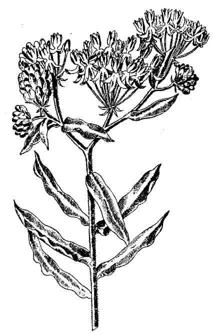

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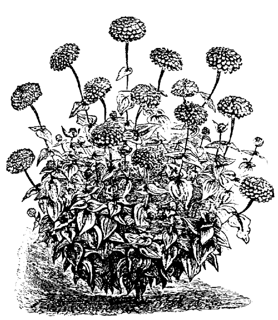


r.

a. Aster
b. Bee Balm (Bergamot)
c. Coreopsis
d. Daylilly
e. Fleabane
f. Goldenrod
g. Chrysanthemum
h. Heliotrope
i. Joe-Pye Weed
j. Marigold
k. Milkweed
l. Phlox
m Sedum
n. Sneezeweed
o. Wild Sunflower
p. Sweet Alyssum
q. Verhonia
r. Zinnia

a. **b.** **c.** **d.** **e.**

Fig. 1. Some common butterfly shrubs and trees of the United States from zone 4–7

a. American Basswood
b. Honeysuckle
c. *Rhus* (Sumac)
d. *Salix* (Willow)
e. Vaccinium

One way we tried to increase the variety of butterfly species in our garden was to plan for a series of seasonal changes in the flowering species present in the garden. Here are a variety of flowering plants, shrubs, and trees which bloom throughout the spring and summer.

Perennials and Annuals

Aeratum houstonianum (ageratum)
Alcea resea (hollyhock)
Asclepias spp. (milkweeds, butterfly weed)
Aster spp. (asters)
Budleia spp. (butterfly bushes)
Chrysanthemum leucanthemum (oxeye daisy)
Chrysanthemum x superbum (shasta daisy)
Coreopsis spp. (coreopsis)
Echinacea purpurea (purple coneflower)
Erigeron spp. (fleabanes)
Eupatorium spp. (bonesets, Joe-Pye weeds)
Grindelia spp. (gum weeds)
Helenium autumnale (sneezeweed)
Helenianthus spp. (sunflowers)
*Heliotropium arborescens (*common heliotrope)
Hemerocallis spp. (daylilies)
Lavandula spp. (lavenders)
Lobularia maritima (sweet alyssum)
Mentha spp. (mints)
Monarda spp. (bee balms)
Phlox spp. (phlox)
Rubedkia spp. (coneflowers)
Salvia spp. (sages)
Sedum spectabile (showy stone crop)
Solidago spp (goldenrods)
Tagetes patula (french marigold)
Thymus spp. (thymes)
Verbena spp. (verbenas)
Verbonia spp. (ironweeds)
Zinnia spp. (zinnias)

Trees and Shrubs

Chrysothamnus nauseosus (gray rabbitbush)
Lugustrum spp. (privets)
Lonicera spp. (honeysuckles)
Rhus spp. (sumacs)
Salix spp. (willows)
Syringa vulgaris (common lilac)
Tilia americana (baswood)
Vaccinium spp. (blueberries)

Planning and building a butterfly garden demands a good understanding of the types of plants and habitat butterflies need to live, produce eggs (the ovum), and transform from caterpillar (larvae) to the chrysalis (pupae) and back to a butterfly (adult). Nectar for adults, foliage for the larvae, and cover for the pupae are necessary. But butterflies also need windscreen plants to shelter from the wind, sunning spots (stones for example), and water for drinking. Building a small rock pool is a worthwhile project for students. The pool should be lined with plastic to prevent the water from draining, but be shallow enough to evaporate the water before it stagnates with mosquitoes and algae.

It is important for students to identify caterpillars to determine whether they are a garden pest or a desirable butterfly in-waiting. Spraying a bacterial pesticide on what might seem to be an area abundant with striped parsley worms munching on your dill and carrots would wipe out the beautiful black swallowtail. Once properly identified, caterpillars can be removed by hand and placed to another part of the garden to a spot that could be specifically planted with their food and used as a an exclusive feeding ground.

Flight of the Monarch

Perhaps the best-known species of butterfly, the monarch is the only migratory species, flying up to 3,000 miles to reach its wintering grounds high in an evergreen forest in Mexico's Sierra Mountains. For years, this haven was a well-kept secret. Scientists knew of the monarch's winter migration, but exactly where they wintered was a question that seemed to elude them. Locals in the Sierra Madres, however, were familiar with the clouds of black and orange monarchs that would descend each winter in their mountain stronghold. It was only a matter of time before two scientists, moving in tandem with the migrating butterflies, and often at opposed and competing viewpoints, finally tracked them down to a stand of oyecher trees in the mountains near Mexico City.

Most birds learn to leave the handsome black and orange monarch butterfly alone. Monarch larvae, the caterpillars, store poisons in their bodies from the milkweed plant. Experiments have shown that once a bird eats a monarch, the bird will not touch a monarch again. The butterfly's pattern and color are memorable; the bird remembers what the monarchs look like and also remembers not to touch them.

Today, The Monarch Site is a web-based site for classroom involvement in raising and tracking monarch butterflies.

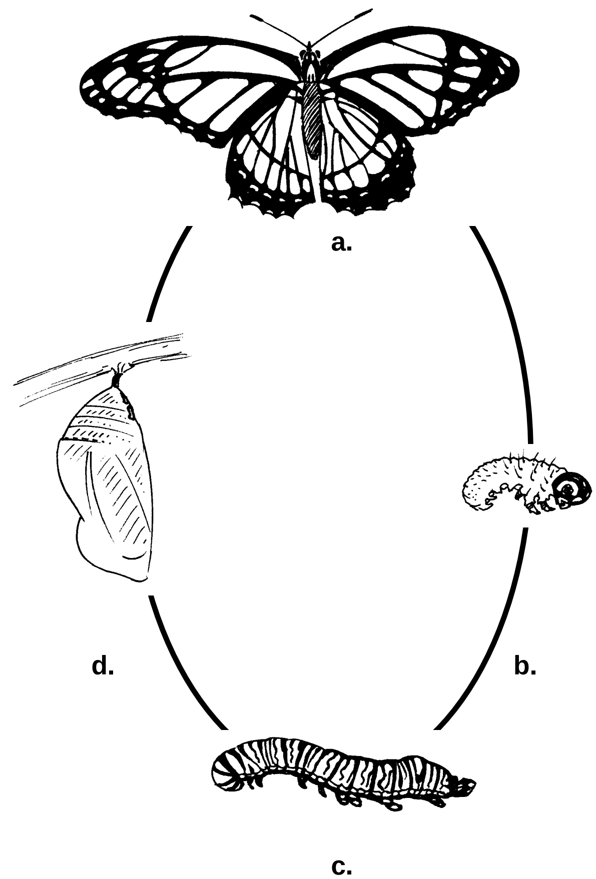


Fig.4 Life cycle of the Monarch butterfly.
a. Adult butterfly
b. Larva
c. Caterpillar
d. Chrysalis

Honeybees, Bumblebees, and Bee Flowers

Most bee-pollinated flowers are yellow, blue, or white. This corresponds exactly to the color vision of bees, as demonstrated by Karl von Frisch (1950). Students should be fascinated by his simple, elegant experiments and it would be interesting to replicate some of them in class.

To find if bees could detect the color blue, he laid out 15 small squares of varying gray shades and one square of blue paper, arranged into a large square. All of the pieces of paper contained a watchglass, but all were empty except the one on the blue paper, which contained sugar. Naturally, the bees were attracted to this square. He changed the position of the blue square often and the bees always found the sugar water. Now he removed the sugar water. Although there was nothing attracting the bees, they still always landed on the blue square, no matter where von Frisch placed it. In other words, they were trained to respond to blue.

Von Frisch successfully repeated this experiment using yellow, but when he tried training the bees to a red square, it proved to be impossible. Evidently, bees see red as another shade of gray and are “red-blind,” unlike humans.

Further experiments by other scientists have shown that bees are actually sensitive to two other colors, blue-green and ultraviolet. They can be trained to cards that reflect UV, which of course we humans cannot see. Many flowers actually look very different to bees than they do to us. For instance, bee flowers often have nectar guides on their petals. These are spots or lines that point the bee to the interior of the flower where the nectar is located. Thirty percent of bee-pollinated flowers have patterns that are clearly visible to the human eye but another twenty-six percent have UV patterns that are visible only to the eye of a bee (Proctor and Yeo, 1973). It is intriguing for high school students to realize that lowly insects can see something that they can’t.

White flowers all look approximately the same color to the human eye, but not to bees. Many white flowers absorb ultraviolet and therefore appear as blue-green to the bees’ eyes. (Blue-green and UV are complementary colors and when one is removed by absorption from white light, the other becomes visible.)

Bees have always been attracted to the European poppy, a bright red flower, and are among its main pollinators. This seems strange in the light of von Frisch’s experiments showing that bees can’t see red, but the mystery was cleared up when it was discovered that poppies strongly reflect ultraviolet light. The bee is not seeing the poppy as “red” but rather as the color “ultraviolet” which is invisible to us.

The scent of a flower is important too to bee pollination. When a worker bee returns to the hive, the scent of the flowers visited clings to her body. The other workers detect this scent by means of their antennae and then, guided by the dance of the returning bee (von Frisch, 1950) they fly out to seek the same flowers. Because of this scent message, bees are very specific pollinators. Once they have started working one kind of flower, they will continue until these nectar and pollen supplies are exhausted. This ensures efficient cross-pollination; bee flowers usually have a high percent of fertilized seeds (Grant, 1951).

There is one interesting exception to efficient pollination by bees, however (Webster, 1979). The production of apples depends on bees; growers usually place a colony of honeybees in every three acres of orchard in order to ensure pollination of flowers and subsequent development of fruit.

However, it has been obvious for years that yields of Delicious apples have always been much lower than that of other varieties. A graduate student at Cornell felt that the problem might be one of pollination and over the next two years he observed thousands of honeybees in action in orchards. He discovered that in the flowers of Delicious apples, the bees could push through the gaps in the stamens and steal nectar without ever touching the stigmas. Thus little pollination occurred. This meant that over 20 million bushels of Delicious apples did not develop each year. One solution may be to put two colonies of bees in each acre of orchard.

The main types of bees in the United States are honeybees and bumblebees. Our bumblebees are native insects but honeybees are descendants of bees brought over by early settlers. The Indians used to call them “white man’s flies.”

These two bees are similar in many respects and they compete fiercely for many of the same flowers, both wild flowers and crop plants. We are dependent on bees for the following fruits and vegetables: apples, pears, squash, cantaloupe, avocado, pumpkin, raspberry, watermelon, peach, plum and blueberries (Rahn, 1975).

In the summer of 1970 in Maine, there was a dramatic demonstration of the relationship of bees and blueberries (Heinrich, 1979). There had been serious infestations of spruce budworms for years. DDT was effective, but it was taking its toll of fish and birds, so that summer a new poison called Fenitrothion was sprayed on millions of acres of forests. This spray, unlike DDT, is lethal to bees. Most of them died and as a result there was no blueberry crop that summer.

There are some flowers that are pollinated only by bumblebees and not by honeybees. These are flowers that require greater strength to open or else have deeply hidden nectaries. Some of these “bumblebee flowers” are snapdragon, butter and eggs, red clover, monkshood, jewelweed and Solomon’s seal.

Flavio holds a honey bee in his hand gently by the wings in order to administer a bee sting to his aunt. In Honduras, one way that Flavio earned money was selling bee stings to arthritis sufferers. The stings contain folic acid. I asked my brother that is a surgeon about it but he said that clinical results were negative. Flavio countered that it depends on the flower that the bee is feeding on. He prefers roses.

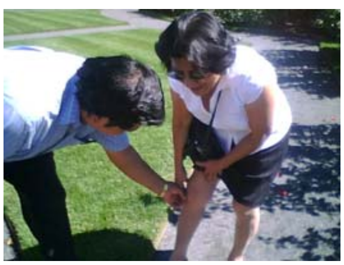


Photo taken on Apr.15 showint thousands of bees clothing Wang Dalin, a well-known beekeeper in Zigui County, central China's Hubei Province. Wang started to raise bees in 1991 and in the past years, he kept company or even made friends with bees. He knows bees' habits like the back of his hands. Now he raises 120 boxes of bees with an annual honey output of some 40,000 jins.

Exercise
6 - 1

WIND AND INSECT POLLINATED FLOWERS

Objectives:

Now that students have learned the main parts of a flower, they should be able to contrast an insect-pollinated and a wind-pollinated flower.

Materials:

- Powerful hand lenses
- Insect-pollinated flower: daffodil, gladiolus, rhododendron, forsythia, snapdragon
- Wind-pollinated flower: oak, walnut, birch, poplar, plantain, grasses

Information for Students:

As you saw in the flower dissection exercise, flowers contain both male and female sex organs. However, a plant normally can't fertilize itself, and the male pollen must get from the stamen of one plant to the stigma of another. Since plants are anchored in the ground by their roots they obviously can't move around. Therefore they either depend on insects or wind to carry the pollen.

Insects visit flowers that have large attractive petals, an enticing odor, nectar (sugar water) and nutritious pollen. As they move from flower to flower, the tiny pollen grains stick on them and then rub off on the next stigma.

Other flowers are not attractive and are not visited by insects. Their pollen is carried from flower to flower by wind. These flowers have no nectar, petals, or scent.

Procedure:

Students will create a chart using the categories below using information about two different flowers

Flower I Flower II

1. odor
2. sepals, number and color
3. petals, number color and nectar guides
4. stamen number
5. pollen grains (draw as large as possible)
6. stigma, sticky or feathery
7. ovary, number of ovules

Lesson
6 - 1

Exercise 1

SKILLS

Knowledge of the parts of plants

Maintaining seedlings

Observation

Recording

VOCABULARY

Nectar

Pollen

Exercise
6 - 2
WIND AND INSECT POLLINATED FLOWERS

Questions on Exercise 6 - 1:

1. You have just studied two different flowers. Which of the flowers has petals? What color are they?

____

____

2. Does either flower have an odor? What does it smell like?

____

____

3. When you shake the two flowers, which one releases pollen?

____

____

4. How does the pollen of the two flowers look different under the lens?

____

____

5. Which flower is adapted to attract insects? Give all the reasons why.

____

____

____

6. Which flower is adapted for wind pollination and why?

____

____

____

Exercise
6 - 2

Lesson 3: A Look at Pollinating Insects

Objectives:

To examine four different insects to see how they are adapted to the pollination of flowers.

Materials: (per each per group of 4 students)

- Nets
- Glass bottles
- Honeybees
- Bumblebees
- Butterflies
- Moths
- Powerful hand lenses

Procedure:

1. Carefully trap insects. Bees can be handled gently by the resident gardeners by the wings. This exercise is not to be done by individuals with allergies to bee stings.

2. Place captured insects in glass bottles. They will be released at the end of the experiment.

3. Using a hand lens, observe as much as possible about the following features. Then draw and label.

HONEYBEE: antennae, mouthparts, compound eyes, furry body, pollen baskets, stinger

BUMBLEBEE: same as honeybee, but observe longer mouthparts and more powerful bodies

BUTTERFLY: antennae with knobs, long tubular mouthparts, compound eyes

MOTH: feathery antennae, long tubular mouth-parts, compound eyes.

B. Examine the insects under the hand lens. Draw what you see and label.

Lesson
6 - 2

Exercise 2

SKILLS

Catching insects

Drawing

Making observations

VOCABULARY

Antennae

Centimeters

Compound eyes

Tubular mouth parts

Exercise
6 - 3

IDENTIFYING THE POLLINATORS BY LOOKING AT FLOWERS

Objectives:

To look at a wide variety of flowers and to decide from their structure how they might be pollinated.

Materials:

There should be plenty of flowers available from vacant lots, trees, and gardens by the middle to the end of May. Some of the possibilities are:

- Wind-pollinated: grasses, plantain, dock, trees mentioned in text.
- Bee-pollinated: fruit tree blossoms, lilacs, rhododendron, lily-of-the-valley, white clover
- Bumblebee-pollinated: snapdragon, violets, red clover, daffodils
- Butterfly-pollinated: columbine, lilies, phlox
- Moth-pollinated: bindweed, honeysuckle, nicotania, yucca

Instructions to Students:

Examine each flower carefully. Write down the name, how you think it is pollinated, and all the reasons for your choice.

There will be a general class discussion after the exercise.

Instructions to the Teacher:

The post-lab discussion should emphasize each student's observations and reasoning abilities. After a consensus has been reached on the pollinator for each flower, the teacher would ask how these plants and animals have become so well-adapted to one another.

Lesson
6 - 3

Exercise 3

SKILLS

Identifying and collecting flowers

Understanding of the mutual adaptation that is co-evolution

VOCABULARY

Adaptation

Evolution

Structure

Appendix

Flowers and Their Adaptations to Various Pollinators

A. *Wind-Pollinated Flowers*

Characteristics of Wind-Pollinated Flowers: Reduced or absent petals or sepals, no nectar or scent, stamens move freely in wind, releasing dry powdery pollen grains, stigma is exposed and often feathery, male and female sex organs may be in separate flowers.

B. *Butterfly-Pollinated flowers*

Characteristics of Butterfly-Pollinated flowers: Bright colors, including red and orange, often deep corollas of spurs containing nectar, weak scent, contain a landing platform, open in the daytime.

(Bumblebees, with their long proboscis may often pollinate these flowers.)

petunia x2

C. Moth-Pollinated flowers

Characteristics of moth-pollinated flowers: Pale, open at night heavy sweet odor, no landing platform

honeysuckle x3

D. *Bee-Pollinated Flowers* (either honeybee or bumblebee):

Characteristics of Bee-Pollinated flowers: Colors are usually blue, white, or yellow. There are often nectar guides on the petals. Flowers have an open form and are often sweetly scented.

mountain laurel x3

buttercup x3

E. *Bumblebee-Pollinated flowers*:

Characteristics of Bumblebee-Pollinated Flowers: It often requires strength to enter these flowers. Only a bumblebee is powerful enough to separate the upper and lower lips in order to reach the nectar of a snapdragon. The nectar may also be at the end of a long spur.

butter and eggs x 5

snapdragon x1

Bibliography

Nabhan, Gary Paul., *The forgotten pollinators* / Stephen L. Buchmann and Gary Paul Nabhan ; with a foreword by Edward O. Wilson ; illustrations by Paul Mirocha., Washington D.C. : Island Press/Shearwater Books , 1996

Knight, David C. **,** Wolff, Barbara. , *Bees can't fly, but they do: things that are still a mystery to science* / by David C. Knight ; illustrated by Barbara Wolff., New York : Macmillan, 1976

Ellis, Barbara W., *Attracting birds & butterflies* : how to plan and plant a backyard habitat / Barbara Ellis., Boston MA : Houghton Mifflin, 1997

Schneck, Marcus, *Butterflies--how to identify and attract them to your garden* / Marcus Schneck ; foreword by Rick Mikula., Emmaus Pa. : Rodale Press ; [New York N.Y.] : Distributed in the book trade by St. Martin's Press , 1990

Tufts, Craig., Loewer, H. Peter., *National Wildlife Federation., The National Wildlife Federation's guide to gardening for wildlife : how to create a beautiful backyard habitat for birds, butterflies, and other wildlife* / Craig Tufts and Peter Loewer., Emmaus Pa. : Rodale Press ; [New York] : Distributed to the book trade by St. Martin's Press, 1995

Chapter 7: Indoor Planting

Performance Objectives

By now, your soil work (as described in Chapter 4) will be completed. Students will be able to:

- Select appropriate indoor planting sites from available space.
- Describe various greenhouse types and their uses.
- Set up an indoor space to be used for planting including greenhouse space.
- Prepare various indoor soils, identifying the constituent parts.
- Dissect a seed.
- Make and care for an indoor planting.
- Transplant seedlings.
- Implement organic pest control methods in indoor space.

Assessment will be based on several criteria:

- The student will be responsible for setting up the indoor planting site.
- The site must be maintained in a healthy state.
- The student will be responsible for producing a crop of healthy seedlings.
- Each member of the group will be evaluated individually. (A group evaluation will also be given.)

Lesson
7 - 1

SKILLS

Ability to extend mathematics to a specific measurement problem

Indoor pest control

Knowledge of the anatomy of a seed

Knowledge of indoor planting

Mixing soil-less mixtures

Preparing an indoor space for planting

Time management

VOCABULARY

Arable land

Biological control

Bio pesticide

Cold frame

Conventional pesticide

Cultural practices

Environmental control

Greenhouse

Hydroponics

Planting mediums

Falling asleep while reading the Encyclopedia of Gardening, I awake with the thought that it is time to go to sleep. Absentmindedly, I open the bible at my elbow to a random page. Superstitious panic chills me when realize what I have done. Faintly nauseous, I read the passage: some seeds fell on stony ground and were eaten by birds; others feel on the wayside, sprung up but then withered; but some fell on fertile ground, sprung up and brought forth much fruit. The things about seeds is, as John Amaroso of Cornell says, “They will grow.” In winter 2001 when James was on safari, we didn’t even have seed-starting trays at Rikers Island. We used turkey pans, paper cups, and shallow wooden boxes.

“Should I start the seedlings while you are away?”

“We can’t do intensive seedling production,” James says before he leaves. “The greenhouse is too unreliable, the watering system that Perera and John built doesn’t work, there will be a lock down and when you come back, you will have a greenhouse full of dead seedlings. There is nothing more depressing than a green house full of thousands of dead seedlings,” he says as he boards the jumbo jet bound for safari in India.

“I will help you,” Jaqueline Acosta says (in for 6 months for trafficking, she is a mother of 3 children). Officer Ross brings the women into the greenhouse from Rose M. Singer Jail. “I will be your assistant,” Jacqueline says. At first there is skepticism that the seeds will really grow; several days pass by with no sign of life. I pretend confidence that I don’t really feel.

“2 seeds in each cup,” I say. When my back is turned the students pour in 8, even 10 of the tiny tomato seeds.

“But can it really grow John?”

“If 2 is good, then more is better just in case they don’t grow.”

All of a sudden, one day the benches, tables, and the spaces under the tables are covered with a greenish-grey haze. It is the seedlings! The moisture steams off of the meting ice as the sun warms the green house’s glass plates. Outside it is 30 degrees, inside it is 60 degrees during the day and the weather doesn’t really drop until late night and never really freezes at all. The home-made irrigation system somehow holds together. Each day we have deep discussions about just how much to leave the vents open during the night as the weather warms up. It is late March now, with fine days approaching. On Friday, a bird drunk with rose hips flies straight into the glass house and knocks itself unconscious. Every one stops what they are doing. The group that had never planted a seed before now totally immersed in the experience of setting the seedlings rushes to the door, forgetting that it is locked. They run to the other door and outside. The bird has a broken neck.

“She is a finch,” Jaqueline says pointing to the illustration of a finch in the bird book.

We dig a grave and bury her. James is back. I sneak into the classroom I can see into the greenhouse thousands of sturdy 6–8 inch seedlings line the tables and benches. James holds one in his hand and looks at it. He starts the way a person starts when they realize that they are being observed unbeknownst. “It looks like a tomato plantation in here.” On Sunday I am at my mother’s house; it is now snowing hard. I call James.

“We left the windows open.”

“The seedlings will freeze.”

I do not have Perera’s home phone number. Expecting that everything would be dead when I get in on Monday I am confronted by a room full of happy seedlings. Perera is holding a fat succulent seedling in his hand. “I came in yesterday and closed the windows,” he says.

That year we left tomato, pepper, okra, zucchini, and cucumber seedlings on peoples' front door steps because we had so many.

Fig. 1. The greenhouse at Rikers Island

Most groups will never have a greenhouse, but every group has indoor space available to them where they can grow plants. Indoor plant care is an important skill for students of horticulture. Being able to raise seedlings for the spring planting of those plants that are popular in all climates but which require southern climates to have time enough to germinate outdoors from seed is essential for any serious vegetable gardener or lover of bedding plants. The kind of indoor spaces that are available vary with every group. Some like Bailey Holt House will have atrium space, which though it was being used as a health club when the garden group was getting started, is in fact a virtual greenhouse. Common Ground has a well-lighted penthouse community room, the Bed-Stuy Campaign against Hunger uses the upper floor of a store-front church, HSNY's horticulture program and the Frederick Douglass Academy and the Riverside Theater have true greenhouses. In all of these spaces, plants can grow and with enough light, seedlings fore the spring planting can germinate and settle into adolescence. And for low-light indoor spaces, there are low-light indoor plants.

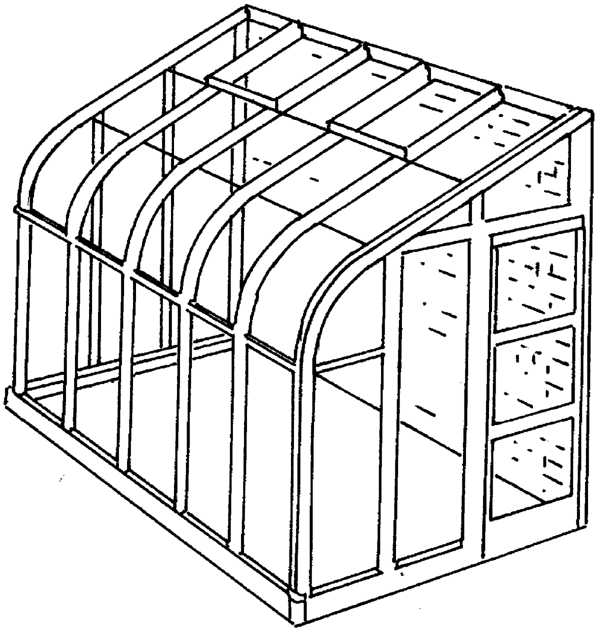
Greenhouses

A greenhouse (also called a glasshouse or hothouse) is a building where plants are cultivated.

A greenhouse is a structure with a glass or plastic roof and frequently glass or plastic walls; it heats up because incoming solar radiation from the sun warms plants, soil, and other things inside the building. Air warmed by the heat from hot interior surfaces is retained in the building by the roof and wall. These structures range in size from small sheds to very large buildings.

Greenhouses can be divided into glass greenhouses and plastic greenhouses. Plastics mostly used are PEfilm and multiwall sheet in PC or PMMA. Commercial glass greenhouses are often high tech production facilities for vegetables or flowers. The glass greenhouses are filled with equipment like screening installations, heating, cooling, lighting, and may be automatically controlled by a computer.

The glass used for a greenhouse works as a selective transmission medium for different spectral frequencies, and its effect is to trap energy within the greenhouse, which heats both the plants and the ground inside it. This warms the air near the ground, and this air is prevented from rising and flowing away. This can be demonstrated by opening a small window near the roof of a greenhouse: the temperature drops considerably. This principle is the basis of the autovent automatic cooling system. Greenhouses thus work by trapping electromagnetic radiation and preventing convection. A miniature greenhouse is known as a cold frame.



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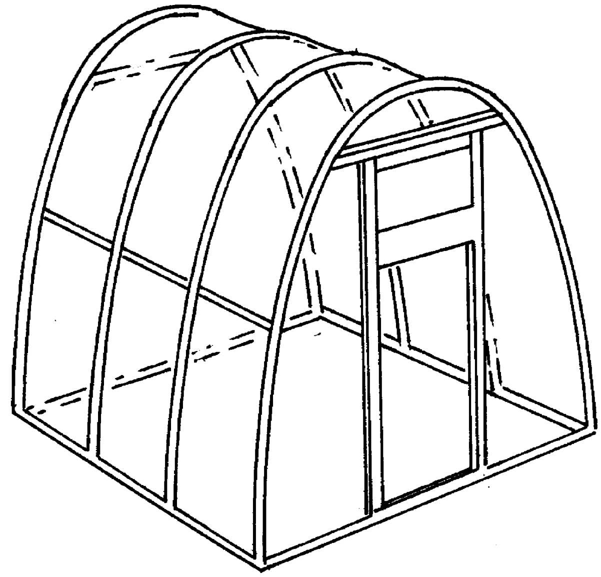

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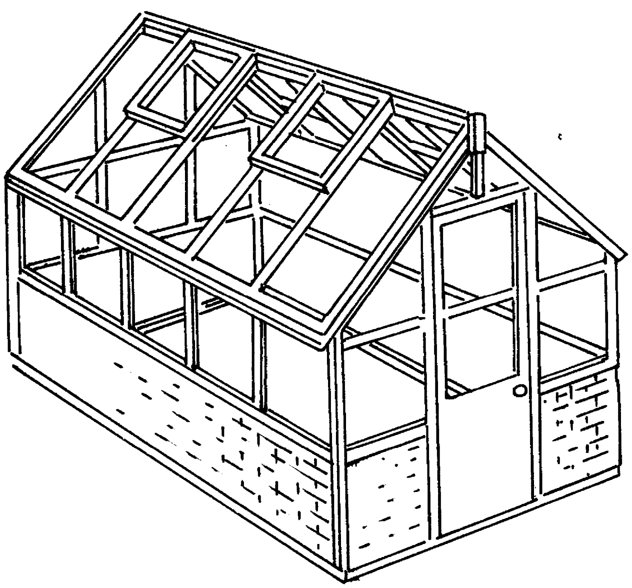

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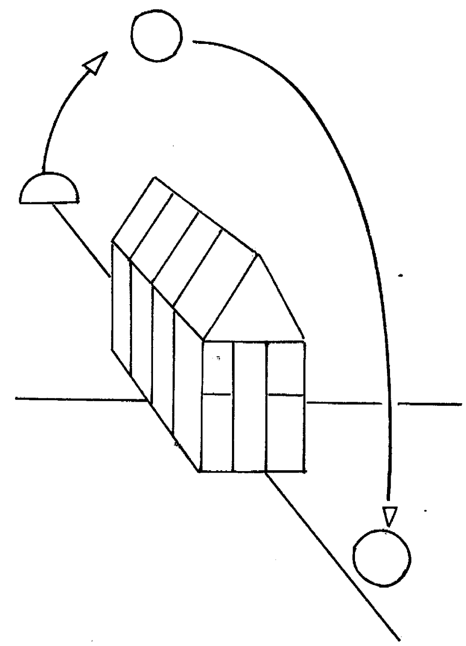


d.

Fig 1. Types of greenhouses
a. Lean-to greenhouse
b. Poly houses are easy to make
c. Traditional greenhouse
d. Orientation to the sun for optimum heating

How indoor planting spaces are used and managed

A basic schedule of indoor planting maintenance

- History of Greenhouse structure and design
- Fall maintenance: The importance of cleanliness: scrubbing the rocks and floor with bleach to sterilize the system against fungi and pathogens. Removal of any weeds or germinated seeds beneath the beds.
- Temperature and light: maintaining and monitoring temperature and light fluctuations in the greenhouse for a diverse mix of plant types.
- Watering: Automatic versus hand. Arranging your benches to ensure that tropicals as well as plants that require drier conditions receive the correct amount of watering.
- Heating and cooling systems: Understanding how these systems work in the greenhouse and ways to maintain them for winter and summer use, including the use of shading.
- Organizing plants in the greenhouse: tropical houseplants, cacti, dwarf fruit trees, and germinating seedlings will have different light and watering requirements.
- Soil mix: for bedding plants and houseplants
- Planting and propagation
- Houseplant care and maintenance

Greenhouses and other indoor planting spaces are often used for growing flowers, vegetables, fruits, and tobacco plants. Bumblebees are the pollinators of choice for most greenhouse pollination, although other types of bees have been used as well as artificial pollination. This helps the plants to produce more offspring for future plantations.

Many vegetables and flowers are grown in greenhouses in late winter and early spring, and then transplanted outside as the weather warms. Started plants are usually available for gardeners in farmers' markets at transplanting time. This is necessary in the north in order for tropical vegetables like tomatoes, peppers, and eggplants to have enough to time to come to fruition during the normal temperate planting season.

The closed environment of indoor planting has its own unique requirements compared with outdoor production. Pests and diseases and extremes of heat and humidity have to be controlled, and irrigation is necessary to provide water. Significant inputs of heat and light may be required, particularly with winter production of warm-weather vegetables. Special greenhouse varieties of certain crops, like tomatoes, are generally used for commercial production.

Greenhouses are increasingly important in the food supply of high latitude countries. One of the largest greenhouse complexes in the world is in Almeria, Spain, where greenhouses cover almost 50,000 acres (200 square kilometers) and where almost 5% of Spain's salad vegetables are grown.

Greenhouses protect crops from too much heat or cold, shield plants from dust storms and blizzards, and help to keep out pests. Light and temperature control allows greenhouses to turn non-arable land into arable land. Greenhouses can feed starving nations in places where crops can't survive in the harsh deserts and Arctic wastes. Hydroponics can be used in greenhouses as well to make the most use of the interior space.

Biologist John Todd invented a greenhouse that turns sewage into water through the natural processes of bacteria, plants, and animals.

History of Greenhouses

Cucumbers reach the ceiling in a greenhouse in Richfield, Minnesota, where market gardeners grew a wide variety of produce for sale in Minneapolis, ca. 1910.

The idea of growing plants in environmentally controlled areas has existed since Roman times. The Roman emperor Tiberius ate a cucumber-like vegetable daily. The Roman gardeners used artificial methods (similar to the greenhouse system) of growing to have it available for his table every day of the year. Cucumbers were planted in wheeled carts which were put in the sun daily, then taken inside to keep them warm at night. The cucumbers were stored under frames or in cucumber houses glazed with either oiled cloth known as "specularia" or with sheets of mica, according to the description by Pliny the Elder.

The first modern greenhouses were built in Italy in the Thirteenth Century to house the exotic plants that explorers brought back from the tropics. They were originally called *giardini botanici* (botanical gardens). The concept of greenhouses soon spread to the Netherlands and then England, along with the plants. Some of these early attempts required enormous amounts of work to close up at night or to winterize. There were serious problems with providing adequate and balanced heat in these early greenhouses.

Jules Charles, a French botanist, is often credited with building the first practical modern greenhouse in Leiden, Holland to grow medicinal tropical plants.

Originally found only on the estates of the rich, with the growth of the science of botany, greenhouses spread to the universities. The French called their first greenhouses orangeries, since they were used to protect orange trees from freezing. As pineapples became popular, pineries, or pineapple pits, were built. Experimentation with the design of greenhouses continued during the Seventeenth Century in Europe as technology produced better glass and construction techniques improved. The greenhouse at the Palace of Versailles is an example of their size and elaborate design; it was more than 500 feet long, 42 feet wide, and 45 feet high.

In the Nineteenth Century the largest greenhouses were built. The conservatory at Kew Gardens in England is a prime example of the Victorian greenhouse. Intended for both horticultural and non-horticultural exhibitions, these included London's Crystal Palace, the New York Crystal Palace and Munich’s Glaspalast. Joseph Paxton, who had experimented with glass and iron in the creation of large greenhouses as the head gardener at Chatsworth, in Derbyshire, working for the Duke of Devonshire, designed and built the first, London's Crystal Palace. Major architectural achievements in monumental greenhouse building were the Royal Greenhouses of Laeken (1874-1895) for King Leopold II of Belgium.

In Japan, the first greenhouse was built in 1880 by Samuel Cocking, a British merchant who exported herbs.

In the Twentieth Century, the geodesic dome was added to the many existing types of greenhouses.

Shadehouse

A shadehouse serves the opposite purpose of a greenhouse; it is used to protect cultivated plants from excessive heat, light, or dryness.

Bibliography

- Cunningham, Anne S. *Crystal Palaces: Garden Conservatories of the United States*. New York: Princeton Architectural Press, 2000.
- Lemmon, Kenneth. *The Covered Garden*. Philadelphia: Dufour, 1963.
- Enoshima Jinja Shrine Botanical Garden
- Muijzenberg, Erwin W B van den. *A History of Greenhouses Institute for Agricultural Engineering*. Netherlands: Wageningen, 1980.
- Vleeschouwer, Olivier de. *Greenhouses and Conservatories*. Paris: Flammarion, 2001.
- Woods, May. *Glass Houses: History of Greenhouses, Orangeries and Conservatories*. London: Aurum Press, 1988.

1. Insect and Disease Problems

Typical insect problems in greenhouses include whiteflies, mites, thrips, aphids and leafminers. Typical disease problems include damping-off (Pythium sp.), Botrytis gray mold, powdery mildew, tobacco mosaic virus and beet pseudo-yellows virus. A number of viral diseases can be vectored by the silverleaf whitefly, including gemini viruses. The best prevention for pseudo-yellows and gemini viruses is to exclude the vector, silverleaf whiteflies. Disease and insect problems typical of field production such as early blight and beet armyworms can also occur in greenhouses, however, particularly those with open sidewalls in vegetable production areas.

2. Biological control

There are a number of beneficial insects available for use against greenhouse pests. In some countries, companies selling biologicals must meet quality standards in terms of number, type, and viability of insect supplied. In the US, there are no such restrictions on suppliers, and the purchaser needs to carefully inspect the material received to determine its condition. If packaging was inadequate, the beneficials may have been crushed. One technique to determine approximate quality is to place the material in a glass jar covered with a fine insect-exclusion screening. If the jar is kept under good conditions for emergence, adult beneficials should be observed within a few days. Parasitoid wasps used to control whiteflies (particularly Eretmocerus eremicus) are very small and difficult to observe, but their movement can generally be detected with the naked eye. Beneficial insects tend to be more sensitive to pesticides than pests. Once beneficials have been introduced into the greenhouse, the types of pesticides that can be used are very restricted. Lists of allowable pesticides are usually available from suppliers.

3. Bio-pesticides

Biopesticides represent a new category of products (sometimes also called biorationals or reduced-risk pesticides) which are safer for humans and have fewer off-target effects. The registration process for these products in the US is streamlined compared to conventional pesticides, making them more likely to be registered for a specialty crop such as greenhouse tomatoes. Materials derived from *Beauvaria bassiana*, an entomopathogenic fungi, are available in several formulations to control whiteflies. These materials can be sprayed on the crop just like conventional pesticides, but like conventional pesticides, applications must also be repeated.

4. Conventional Pesticides

Relatively few conventional pesticides are registered for greenhouse tomato production, and this situation is not likely to change. If anything, fewer new materials are likely to be registered, and older materials are likely to become less effective as pests develop resistances. There are also detrimental effects of most pesticides on bumblebees and introduced beneficial insects. Thus growers should adopt integrated pest management practices rather than relying exclusively on insecticides.

5. Cultural Practices

The best way to control insects is to prevent their entry through air intakes and entryways. Placing screens directly over the air intakes would reduce circulation too much, but screening boxes can be built out around the intakes to allow air to circulate more freely. Charts available from screening manufacturers allow calculation of the volume of these screening boxes. Great care should also be taken to avoid introducing pests through infested transplants or ornamentals, which can be sources of thrips, mites, and whiteflies.

Natural insecticides, such as neem oil, are other types of biopesticides.

Growing Plants from Seed

Fig.8. Growing plants from seed.

We sowed many vegetable seeds in our cool greenhouse. This is vital in climates with cool summers and for vegetables that mature slowly. The health of seedlings is more easily monitored and controlled indoors, especially if you can maintain control of the temperature. Some perennials may need warmer temperatures to germinate. Once seeds have germinated, keep them at lower temperatures to avoid drying out.

Seeds like to germinate out of the direct light. Keep seed trays under benches until they germinate. Later on, transfer them to individual pots and place them on top of the benches. Seedlings need to be moist, not soggy.

But what if we don't have a greenhouse?

A greenhouse is a wonderful resource and if your facility has one then you can teach your students a marketable skill while also being able to reach a very high level of sustainability by raising your own seedlings. A surprising number of places where we work have had greenhouses that were either dormant or in good enough condition to work in. Fredrick Douglas Academy has a small but efficient greenhouse, I just found out that the High School of Science and Math has a greenhouse on their roof that is not being used. Phoenix Academy has a greenhouse that may be able to be repaired and Rikers just got donated a greenhouse for our adolescent program.

Partnering with a facility that has a greenhouse can also be a good way to expose your students to greenhouse culture. The Brooklyn Rescue Mission has an unheated greenhouse that was donated to them by Greenthumb. We work there with kids that were mandated to a vocational education program by the courts. It is a very rudimentary greenhouse with benches and tables made from lumber and cinder block the growing season is short. The greenhouse does not warm up late March and by June it is too hot to grow anything. Then again in the autumn it is usable. So the green houses range from the most basic structure that can extend the growing season in autumn and give an early start to seedlings to ones that are state of the art quality structures. Cost is of course a big factor though the most rudimentary and the most elegant of our greenhouses were both donations. It has been possible to make the connection to greenhouses so that students can have the experience of the kind of carful nursery work that is only possible in a greenhouse. In Fredrick Douglas Academy it is possible to undertake serious experiments throughout the year and we have successfully raised tropical plants and started a hydroponic growing system.

Still in some cases it has just not been possible either to connect to a local group that has a greenhouse or to purchase or get one donated. The next section gives a simple guide to raising plants indoors. Any sunny room can be support seedlings, as long as there is a minimum of 6 hours of sun. The experience of raising seedlings is one of care and nurture and the knowledge, skill and understanding of raising a plant from seed gives the student many opportunities to succeed

As you sow so shall you reap. In a state of the art greenhouse or in a sunny upstairs room the same seeds can be sown by different students and the results will be identical. A student is certainly at least as sensitive to what is sown in them as is a seed. For example Z. was put in charge of the seedlings. The tomatoes flourished, the ochra sprang up the peppers and collards all thrived. A plant will perform miracles if you love her. Try to get you students to look at plants in a new way. Seed starting is enormously powerful redolent with the possibility of new life. Start seeds where every you can.

Seed starting can be done in many indoor spaces. You don't need a greenhouse; any sunny space will work. The bigger the space, the more plants you can start. 4 tables 5 feet by 2 feet can easily support 1,000 plants. At 6-week rotations from March to May, the number reaches 2,000 plants. An atrium space like Bailey Holt House, with 3 available tables, is capable of producing 4,000 plants in a half-year period. The potential to provide ample herb, vegetable, annual, and perennial seedlings to their outdoor space is more than enough. The space can also hold lots of house plants throughout the year.

1. Germination. Seeds are generally easy to germinate and only require moist soil, a steady warm temperature (between 55 and 75 degrees), and adequate light. For depth of planting, the rule of thumb is approximately twice the thickness of each seed.

Space small seeds an inch or so apart, medium seeds 2 inches apart, and large seeds like beans and squashes and pumpkins can usually be planted directly into the ground, especially those that are native species. A humid environment encourages germination: when possible, cover the container or planting trays with a clear plastic "tent." This allows light to come in and maintains moisture. Do not seal completely.

Exercise
7 – 1

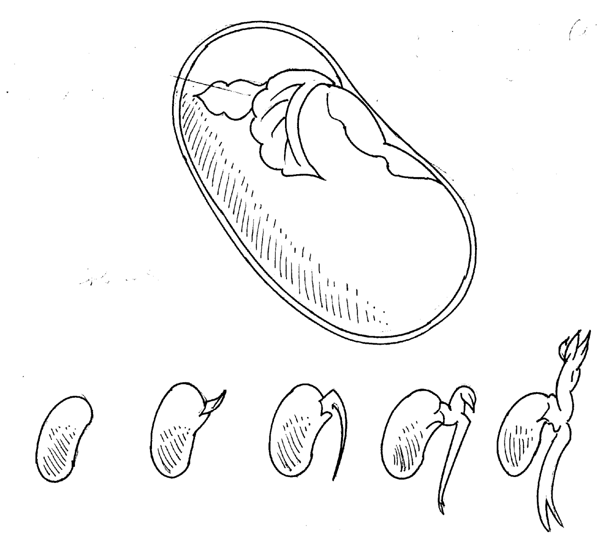
SEED ANATOMY

Materials:

- Several lima beans for each student
- Notebooks and pencils
- bowl of water
- Magnifying glasses
- Biology book

Procedure:

1. Soak half the beans overnight to loosen the seed coat.
2. Compare the dry seed coat to the soaked seed coat.
3. Remove the seed coat carefully from the soaked bean.
4. Observe and record the appearance of the seed coat under a magnifying glass.
5. Split the seed in half and use the magnifier to record details.
6. Look for these parts: embryo, seed coat, cotyledon.
7. Research the purpose of each of the parts of the seed using the biology book and Chapter 2 of this curriculum.
8. In your notebook, make a careful drawing of the seed parts and label them along with your research into the purpose of the parts.



Lesson
7 - 1

Exercise 1

SKILLS

Drawing

Observation

Plant dissection

Recording

Research

VOCABULARY

Cotyledon

Embryo

Seed coat

2. Trouble-shooting. When store-bought seeds have trouble germinating, it is usually because the student planted it too deeply or did not moisten the soil often enough. Students also have a tendency to water directly on top of the planted seed, which presses it into the planting mix or washes it out altogether. For really big greenhouses, irrigation systems work best, but for most indoor planting a finely-articulated watering can works well.

3. Cleaning the space. Make sure that all the containers and tools are thoroughly washed, especially if they are being reused form last year. A solution of warm water and a little bleach will work fine. Wash the table surfaces and tools as well.

Fig. 9 Mixing indoor soils.

Making your own indoor soil is much more economical and gives you greater control over the germination process. We use a tremendous amount of indoor soil during the spring. By the end of the germination season the formula of 2 parts peat moss, 1 part perlite, and 1 part vermiculite has been assimilated by each student.

Once seedlings establish their second set of leaves, it will become necessary to transplant them into a more nutrient-rich soil. Mixing in an equal part of commercial compost or fertilizer with soil-less seed-starting mixture provides the basis of potting soil. Although we make our own compost on the Island, it is too active to use in the greenhouse, especially if it has been lying around the garden for a while.

Soil is a potential medium for all sorts of fungi and viruses, so be very careful about what kind of soil is brought into the greenhouse.

Exercise
7 – 2

MIXING 2 DIFFERENT TYPES OF INDOOR SOIL

Materials:
- Large mixing bowl
- Measuring container such as 6" pot with holes blocked
- Watering can
- 1 capful of bleach
- Perlite (clean sand can be use to replace perlite and vermiculite)
- Vermiculite
- Peat moss
- Commercial compost or manure
  Poster-sized paper and glue
- a good gardening book

Procedure 1. Creating "soil-less" seed starting mix:
- Research the properties of each of the constituent parts of "soil-less" seed starting mix: perlite, vermiculite, and peat moss.
- Mix 1 capful of bleach with 1 gallon of water and sanitize the containers and all implements to insure that there are no pathogens remaining from last season’s use.
- Measure and mix dry 2 parts peat moss, 1 part vermiculite, and 1 part perlite.
- Reserve half the mix for use in procedure 2.
- Add water until the mixture assumes the consistency of a wrung-out sponge.
- Create a poster by drawing a container and gluing 1 part perlite, 1 part vermiculite and 2 parts peat moss in proportion into the container. Into boxes drawn beside each constituent part, label and define the qualities, quantities, and uses of each
- Title the poster "Soil-less" Seed Starting Mix” and state its uses.

Procedure 2. Potting Soil:
Research each importance of compost or manure in the potting soil mixture.

- Sterilize your implements and containers.
- Starting with the "soil-less" seed starting mix, mix in an equal part of commercial compost or manure dry or compost from your own composter.
- Create a poster similar to the one in procedure 1 with the addition of the compost
- Title the poster “Potting Soil” and state its uses.

Lesson
7 - 2

Exercise 2

SKILLS

Cleaning

Creating soil-less planting medium

Knowledge of Soils

Measuring

Observing

Researching

VOCABULARY

Bleach

Consistency

Pathogens

Peat moss

Perlite

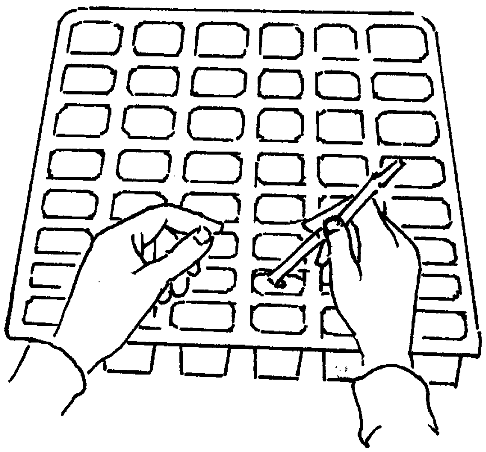
Planting mediums

Potting soil

Soil-less

Vermiculite

a.



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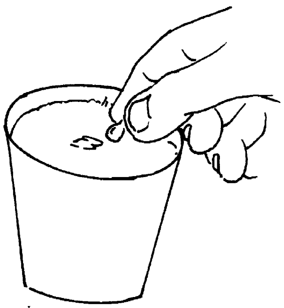

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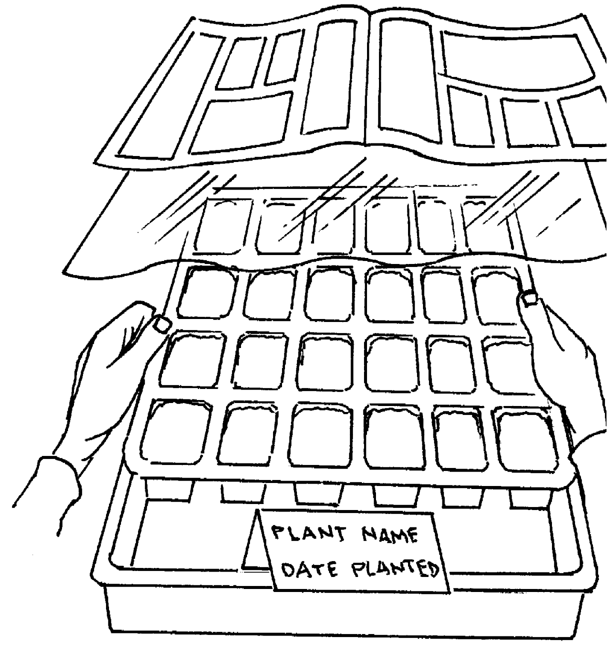
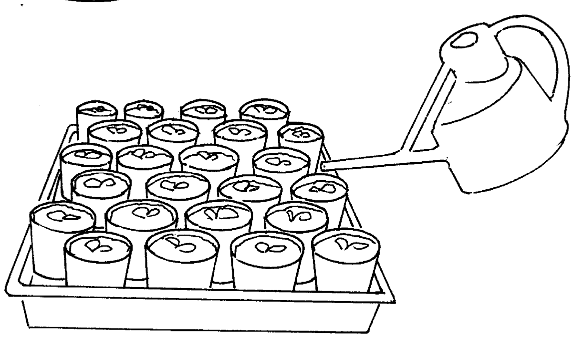


e.



f.

Fig. 10. Sowing seeds indoors

a. Commercial seed cells don’t take up much room in the greenhouse and don’t use much soil. We use recycled ones, but they must be cleaned thoroughly. Seeds germinated in trays work the same way but are more of a challenge to transplant. Fill the container with soil-less seed starting mixture. Plant seeds in a hole about twice the size of the seed. Put 2 seeds in each hole.

b. Place the cell packs into a tray. If you are germinating seeds in trays with holes provided in the bottom for drainage rather than cell packs, you can place them in slightly larger trays. Mist the seeds and put water in the bottom of the trays. Seeds absorb moisture very well by induction.

c, Cover the trays or cell packs with a sheet of plastic to retain humidity and a sheet of newspaper to lessen the effect of direct sunlight. Place them under the greenhouse benches.

d. Large seeds like beans can be germinated directly in individual containers of potting soil.

e. Place the individual containers into trays and water by induction as well as mist

f. Student at the greenhouse germinating seeds. He’s wearing gloves to protect seeds from pathogens.

Exercise

7 – 3

GERMINATING SEEDS IN FLATS CELLS OR INDIVIDUAL CUPS

Materials:

- Soil-less seed-starting mix from Exercise 3
- Individual cell commercial seed starting flats
- Small individual post
- Trays of various kinds of seeds
- Misting bottle
- Paper and indelible markers
- Plastic sheets
- Newspaper
- Gardening book that contains information about seed starting

Procedure 1. Individual Cell Commercial Seed Starting Flats (for Small Seeds):

1. If reusing last year's flats, sterilize as in Exercise 3.
2. Fill each cell with soil-less seed starting mix.
3. Plant seeds to the depth indicated on the seed packet or in the case of seeds collected from your own gardens, research the correct depth in a gardening book.
4. Mist the flats of seeds thoroughly, cover with plastic to keep moisture in, and cover with newspaper to keep light out.
5. Carefully label the flats with the type of seed being germinated and the date.
6. Monitor your seeds. Water from below by putting a little water in the bottom of the tray beneath the individual cells. Newly germinated seeds must be kept moist not soaked!

Procedure 2. Individual Pots (for Large Seeds):

1. Sterilize your implements and containers.
2. Put a small piece of newspaper at the bottom of each pot to keep moisture in.
3. Fill the containers to within about 1/2 inch from the top with potting soil and place two seeds in each to the depth indicated on seed packet or in a gardening book.
4. Place the pots into a tray and put a little water in the bottom of each tray.
5. Mark each tray with the kind of seed planted and the date planted.
6. Cover with plastic and newspaper and place under a bench until first leaves appear.
7. Keep seeds moist and water from below by placing a little water in the tray that carries the pots.

Procedure 3. Trays of Various Kinds

1. Trays can be of 2 kinds—with holes to take in water from below or without.
2. Sterilize the trays if they were used last year.
3. Put a bout an inch of soil-less seed starting mix in each tray.
4. Space the seeds about 1inch apart and cover lightly with 1/4 to 1/2 inch or seed starting mix.
5. Moisten them by misting.
6. Cover with plastic and newspaper and place under benches, or in the case of a cool greenhouse, in a warm place in the classroom.
7. If you are using trays with holes, you can place them into larger trays and put a little water in the bottom of the larger trays.
8. If you are using trays without holes, you will have to monitor the watering more closely.

Watering:

Having the option of watering trays, cells, or pots from below is useful when you cannot be in the greenhouse during the weekends, especially when the greenhouse starts to heat up. You will probably find that some kind of misting system that uses sprinkler heads or drip hoses will be the only way to keep your seedlings alive during the weekends once your greenhouse starts to heat up.

Transplanting

If the plant is native to your gardens, you may have to simulate cool spring conditions for the seed to germinate. Store seeds for about 40 days in a refrigerator at about 40 degrees to break the dormant period. The seeds can be mixed with a little slightly damp perlite in an open container and stirred every few days in the fridge, then planted in the regular manner.

Once the seed has germinated and the first two sets of leaves have emerged, the plants can use a weekly application of fertilizer. We recommend an organic preparation of diluted liquid fish emulsion or other similar compounds with a 10-10-10 solution, rather than the store-bought Miracle Grow, which is made from chemical mixes. The strength should be increased once the plants get larger.

Transplanting begins shortly afterwards, when the plants are 4-5 inches tall, into small pots that will keep the roots contained. Use a potting mix with compost. Transplanting once or twice before planting, helps the seedling develop a strong root system, and ensures its survival during dry weekends or sudden cold snaps in the greenhouse.

a.

Fig 11. Transplanting seedlings.

Carefully remove seedlings from their containers once they have produced their second set of leaves by first loosening the soil around the outside of the container, then lifting the plant out carefully. Take as much of the original soil as possible. Plant into clean 3” containers filled with potting soil.
a. Students at the greenhouse transplanting seedlings into plastic cups.
b. Once seedlings are established, you can water with an ordinary watering can.

b.

Bibliography

Tallack, J. C. , *The book of the greenhouse : with a special chapter on the little town greenhouse* / by J.C. Tallack., London ; New York : J. Lane, 1901

Gill, Stanton, 1952-, Sanderson, John, 1955-, *Ball identification guide to greenhouse pests and beneficials* / by Stanton Gill and John Sanderson., Batavia Ill. : Ball Pub., 1998

Ball, Vic., *The Ball red book : greenhouse growing* / Vic Ball, editor., 14th ed., Reston Va. : Reston Pub. Co., 1985