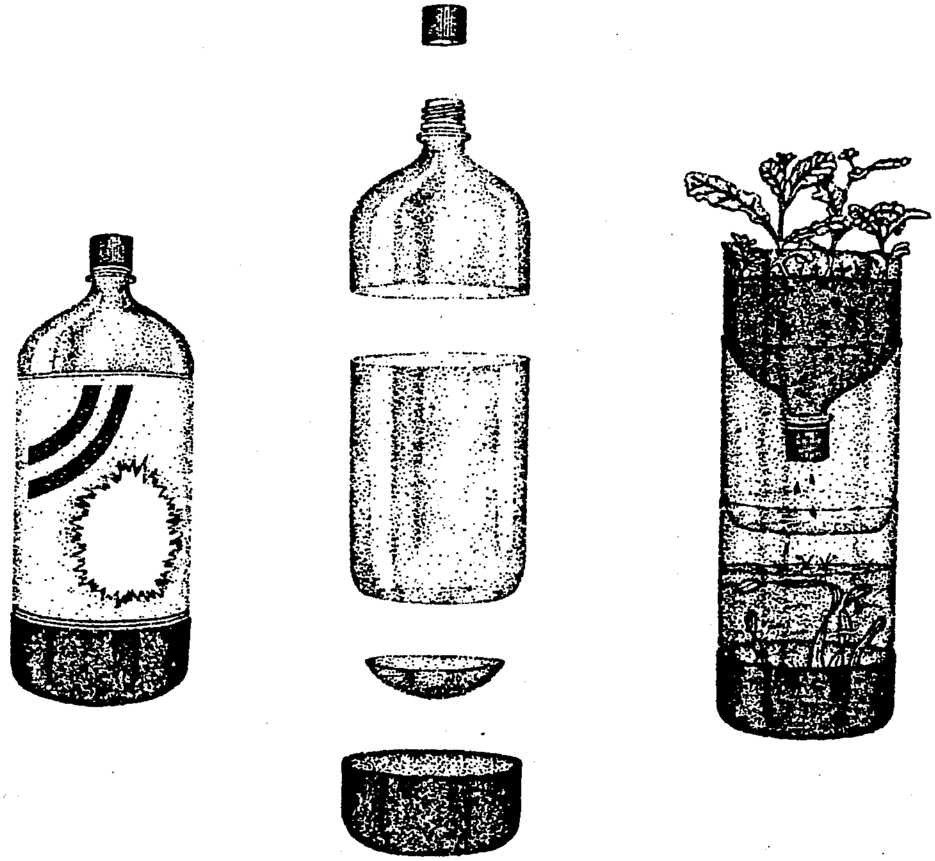
BOTTLE BIOLOGY



Exploring:

- *Ecosystem Interactions*
- *Population Dynamics*
- *Biodegradation*
- *Microbial Fermentation*
- *Experimental Design*

Hands-on Biology with Plastic Containers

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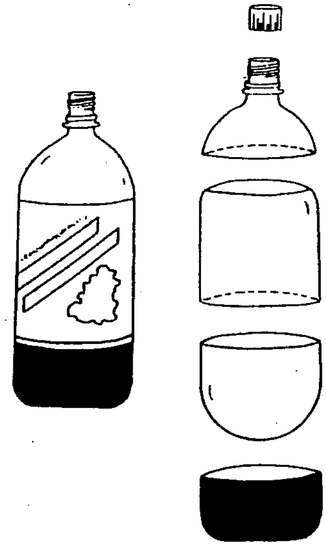

Bottle Biology is a classroom-tested approach to hands-on biology using plastic beverage bottles and other throw-away containers. Designed for biology education at all levels, Bottle Biology offers a low cost way to create a diverse range of experiments and life science explorations leading to a better understanding of ecosystems, local environments and the scientific process.

The main objectives of the project are to develop, publish and distribute instructional materials related to Bottle Biology. A network of scientists, educators, students, parents and others has contributed creative and stimulating ideas for activities. These are being developed into effective educational documents to be disseminated nationally.

Some of the more popular scientific explorations include making composting columns,Korean *kimchee* and sauerkraut fermenters, stacking eco-habitats, insect environments and modelling environmental interactions such as nutrient runoff and groundwater contamination.

Bottle Biology is an instructional materials development program funded by a grant from the National Science Foundation administered by the University of Wisconsin-Madison.

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Bottle Basics

Create hands-on scientific explorations using throw-away containers

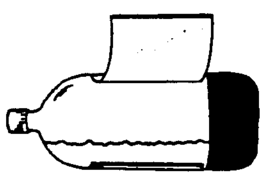
Plastic beverage bottles provide the primary material for Bottle Biology explorations. They are readily available — millions are produced and discarded daily — and they are easy to cut and combine in a wide variety of ways for science projects. These Bottle Basics are meant to get you started, showing how plastic bottles can be taken apart, cut, and connected. Once these basic techniques are mastered, you can use your imagination to combine bottles and parts of bottles (as well as other disposable containers) into the apparatus needed to try out any number of ideas for fascinating projects in the life sciences..

Removing the Label and Base

Both the bottle label and base may be readily removed, but for some projects or parts of projects it might be best to leave the base glued firmly to the bottle. Aquariums and compost columns, for example, will be more stable if the lowest unit has the base attached. In almost all projects the label should be removed. The label and base are held in place with a heat-sensitive glue. To remove them, the glue must be softened with heat.

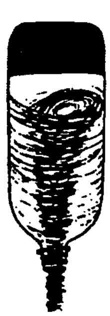
A) Fill the bottle about 1/4 full with very hot (120° - 150° F) water. If the water is too hot (170° - 212° F) the plastic will soften, warp, and may permanently crumple. Screw the cap back on firmly. This will retain pressure inside the bottle allowing you to hold the bottle tightly without crushing or denting it.

B) Tip the bottle on its side so the water warms the area where the label is attached to the bottle — this will soften the glue. Catch a corner of the label with your fingernail and gently peel it from the bottle. If there is resistance, you may need hotter water.



C) To remove the base, tip the bottle upright so the hot water warms the glue holding the bottle bottom to the base. Hold the bottle tightly and slowly twist off the base.

D) Remove the cap and pour the water out slowly. You might try swirling the bottle around as it begins to empty, causing the water to form a vortex resembling a tornado funnel. This lets the water to swirl slowly out of the bottle mouth without buckling the sides.



E) Usually most of the glue from the label and base is left on the bottle. It can be removed by scraping with a sharp-edged piece of metal or plastic while the glue is still warm. It can also be chemically softened and removed with a solvent such as cleaning fluid. Put a small amount on a paper towel and rub. This works best if most of the glue has been removed by scraping. Be sure there is adequate ventilation.

F) Save all parts, bottle, cap, and base. You now have the raw materials to begin fascinating explorations!

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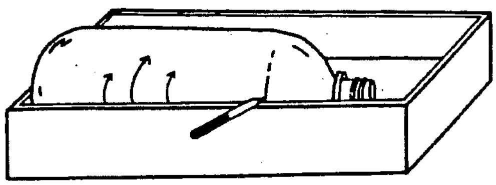
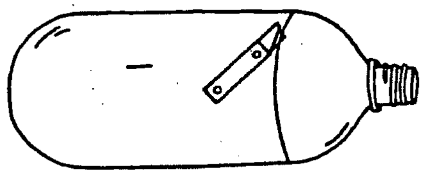
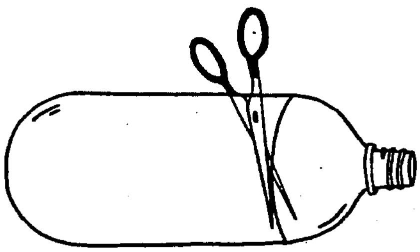
Bottle Basics - Cutting Techniques

Plastic bottles can be cut and modified in a great variety of ways — but before you begin cutting, plan carefully. Remember that some bottles are wider than others, some have larger bases, and some have more tapered shoulders. The bottle shape and location of the cuts affect how your pieces fit together.





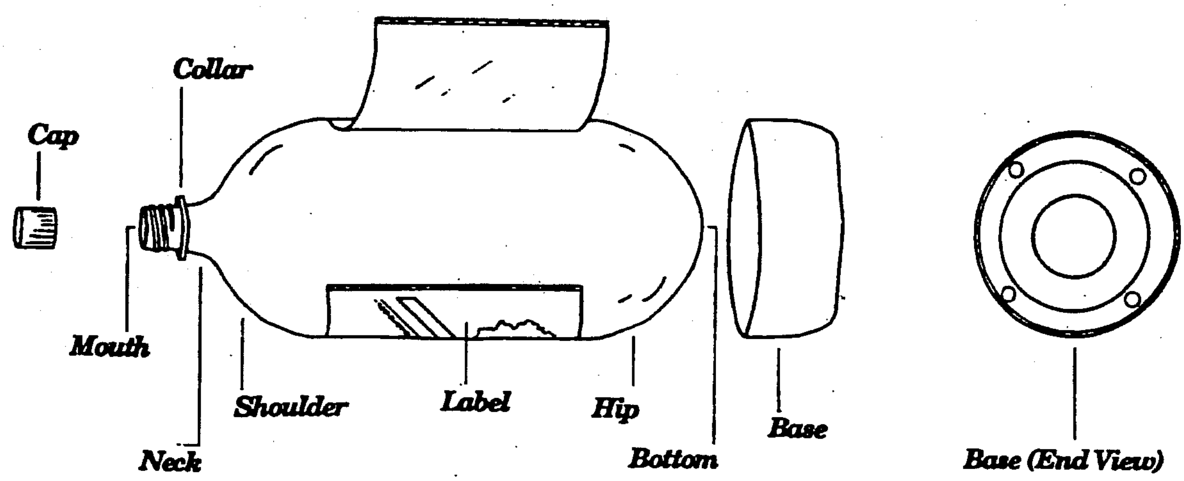
1) Place bottles on their sides in an empty drawer, tray, or box — shallow cardboard flats and computer paper boxtops work well. Hold the bottle up against the side and corner of the box to stabilize it while rotating. Brace a felt-tip pen against the box with the tip just touching the bottle and roll the bottle slowly around. This will leave an even line encircling the bottle. Sometimes it's easier to do this cooperatively. One person holds the bottle and rotates, while the other keeps the pen tip touching the bottle.



2) Use a single-sided razor blade or utility knife to begin the cut, slicing along the cutting line about two inches. Insert the tip of the scissors and snip your way around the rest of the cutting line. Because the scissor blades tend to catch in the plastic, it may be easier to snip along with just the tips.

Trim away rough edges and irregularities with the scissors. Once the bottle is cut open, you can snip more from the shoulder, hip or side if you decide shorter lengths are needed. When in doubt about how project pieces may fit, cut them a little too long — you can always remove the extra length. Because it is more difficult to draw lines once a bottle has been cut, draw all intended lines before cutting.

Basic Bottle Anatomy



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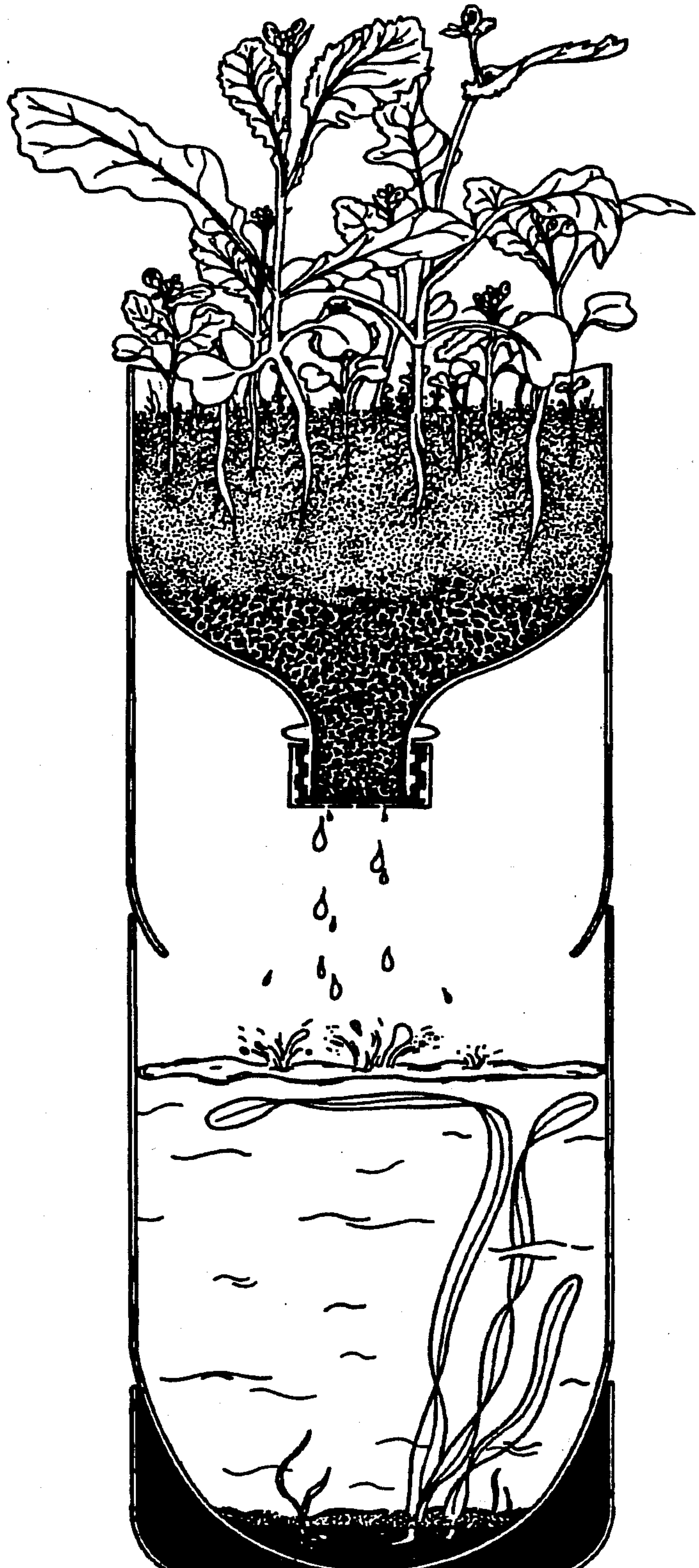
TerrAqua Column

Explore interactions between terrestrial and aquatic systems

Terrestrial and aquatic ecosystems are frequently viewed as two separate and independent entities. However, land and water systems are connected in many ways. One of the major links between terrestrial and aquatic ecosystems is water.

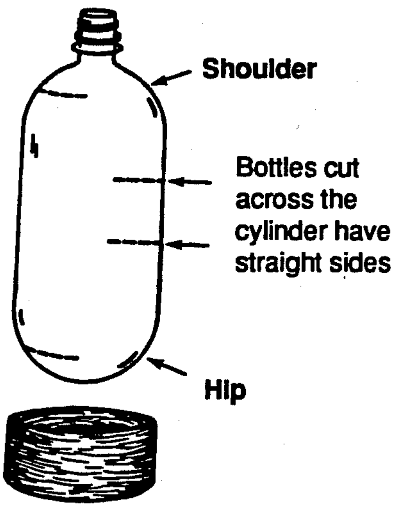
Water is the life blood for the terrestrial community and usually finds its way to wetlands, rivers, lakes and oceans. Passing through the soils of fields and forests, the water picks up compounds such as nutrients and agricultural chemicals. As this solution enters an aquatic community it then modifies biological, physical and chemical aspects of that community.

Construction of a TerrAqua Column can allow you to model and explore relationships between land and water ecosystems.



Bottle Anatomy

Bottles cut across the shoulder or hip have tapered sides



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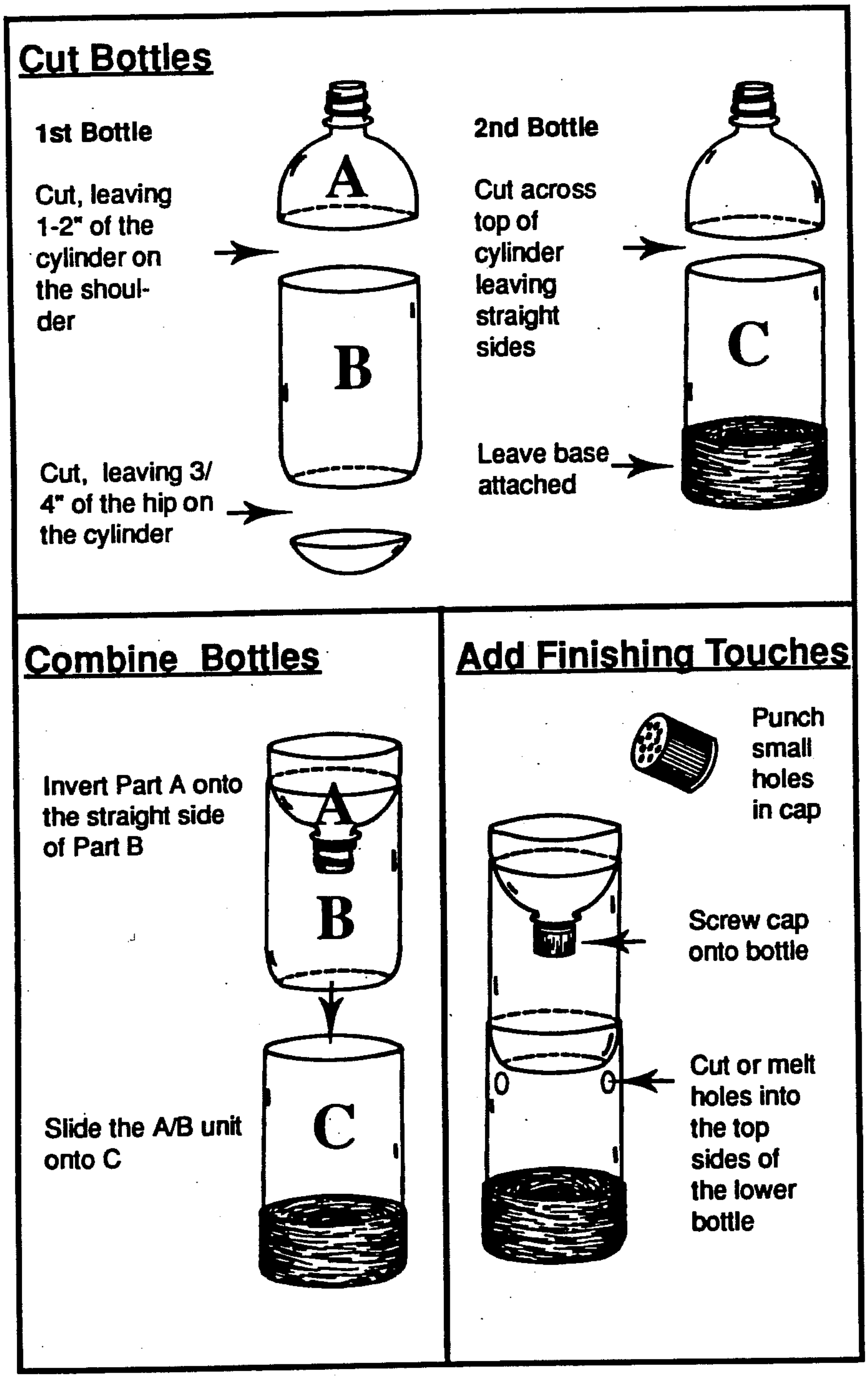

Column Construction

This column is composed of two units. The upper, terrestrial unit is made by cutting a bottle to make pieces A and B as shown in the illustration. These two pieces can be held together by a wide transparent tape such as bookbinding or mailing tape. The lower, aquatic unit is made by cutting a second bottle to produce piece C. Biological materials for the aquatic system can come from a pond, lake, puddle or fish tank and can include algae, phytoplankton, zooplankton, aquatic plants and insects. A variety of plants can be used in the terrestrial system. Because of their rapid life cycle, Fast Plants work well.

Studying the Flow of Agricultural Chemicals

Recent concerns about the interaction between land use and water quality have led to the study of nutrient and chemical flow from terrestrial to aquatic ecosystems. Fertilizers and pesticides used for lawn care and agriculture readily make their way into aquatic systems causing water quality problems ranging from algal growth to the build-up of toxins in drinking water.

The TerrAqua Column allows for the study of various aspects of land-water interactions such as the effects of:

1. Nutrient sources for the terrestrial system
2. Nutrient concentration
3. Type and amount of soil in the terrestrial system
4. Type(s) of plants in the terrestrial system
5. Physical factors such as temperature and light
6. Effect of various pesticides
7. Frequency of fertilizer or pesticide application.

Various aspects of the terrestrial and aquatic systems can be monitored such as the growth of plants and algae. For plants in the terrestrial system, percent germination, height, weight, leaf size, length of life cycle, and seed production can all be measures of plant health. Populations of algae, aquatic plants and animals can be monitored in aquatic systems. Changes in the soil microorganism populations and soil structure can also be monitored. Finally, the solution flowing from the terrestrial to the aquatic system can be examined with a Fast Plant bioassay (*Fast Plant Notes*, Spring, 1990).

BOTTLE BIOLOGY

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Compost Columns

Where do things go when they die?
Explore the process of decomposition.

Composting is based on the biological process of decomposition. What turns plants and animals into compost? Microscopic bacteria and fungi, which feed on dead tissue, are the chief agents.

What affects the composting process? The amount of moisture and air, temperature, light, sources of bacteria and fungi, and the nature of the decomposing material are all critical. The presence or absence of air (oxygen) is one of the most important factors in composting. The practice of composting allows air and moisture to speed the natural process of biodegradation. Making a compost column lets you see and experiment with this process, and witness nature's world of recycling.

Materials Needed:

- Three 2-liter plastic beverage bottles
- Hot tap water, knife or razor blade, scissors, marking pen, sharp needles for poking holes, clear tape, netting or mesh fabric, rubber bands.
- Organic materials for composting, such as kitchen scraps, leaves, newspapers, animal manure, and grass clippings.

Procedure:

Remove the bases from two bottles, and the labels from all three, by pouring about two cups of hot tap water into the bottles. (Columns can also be made from bottles that don't have removable bases.) Replace the cap, tilt the bottle so the water softens the heat-sensitive glue, peel off the label and twist off the base. Pour out the water, draw cutting lines around the bottle, make incisions with the knife and cut with scissors and assemble as illustrated.

Most columns will require air holes for ventilation, and these can be poked into the plastic with a sharp cold needle or with a needle or paper clip heated in a candle flame. Alternatively, larger holes can be cut into the sides with the knife and covered with fine mesh fabric held in place with tape. A piece of mesh fabric over the lower end allows for drainage. Refer to the illustrations. Add ingredients for composting through the top of the column.

Explorations:

The possibilities for compost column explorations and discoveries are endless. There is no limit to what can be put inside, or the conditions under which the column can be kept. In addition to simply observing changes, you can design experiments which explore the effects of variables on you column.

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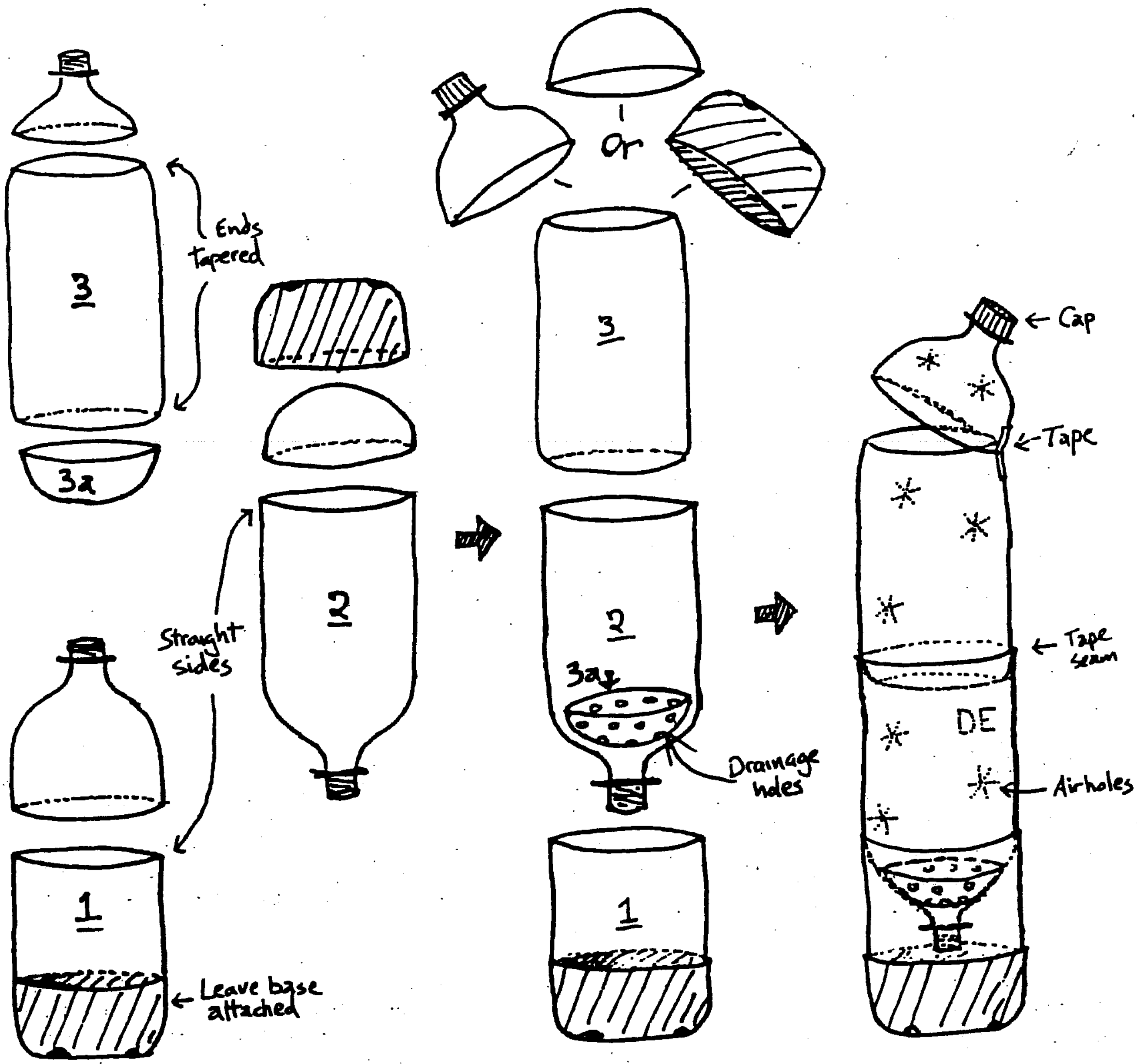
Compost Column Construction



Two Possible Explorations:

- **Leaf Digester.** Make two columns, and use a balance or postal scale to weigh out two equal quantities of leaves. Loosely pack one column with leaves only. Mix about a half cup of garden soil to the other batch of leaves and loosely pack the second column. Pour equal amounts of pond or rainwater into each column, and wait several hours for it to percolate through. If none comes out the bottom, add more in equal amounts until about a half cup drips into the reservior. Schedule a rainstorm to occur in the column every few days, pouring the drippings back through the column. Which column decomposes faster and why?

- **Compost Tea.** Compost columns can be used to generate a liquid fertilizer called "compost tea". Try making several columns using different ingredients, whose drippings will differ in color and chemistry. Use this liquid to water and fertilize identical sets of seedlings to see how different brands of "tea" affect plant growth. Some drippings, such as those from a column filled with leaves from a black walnut tree, may even inhibit growth.

BOTTLE BIOLOGY
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EcoColumns

Creating miniature systems that can be interconnected to explore natural systems

This advanced Bottle Biology activity makes possible a fascinating variety of dynamic life sciences explorations. EcoColumns can be designed to model many kinds of aquatic and terrestrial environments, with habitats and niches for insects, spiders and small vertebrates. Individual modules can be used alone or stacked into a stable, free-standing column. Modules can be kept isolated from one another or be interconnected to stimulate interactions between systems.

The tapered sides of the Eco-Column chambers allow a closeup view of organisms from aquatic environments. Roots of plants are also made visible, and the module can be viewed from underneath as well. Studies of ecology, population dynamics, water chemistry and many other sciences can be conducted in an Eco-Column. Columns can also simply be constructed and observed, noting changes over time. There is no limit to the number of ways that the modules can be designed and put together. What kind of biological question could you try to answer in an EcoColumn?

Materials:

- Several one or two liter beverage bottles
- Bottle Basics tools for marking and cutting bottles, plus equipment for making ventilation and port holes
- Clear waterproof tape (Most postal and bookbinding tapes are waterproof.)
- Silicone sealant (Available at most hardware stores, for chambers that will need to hold water.)

Explorations

- Consider the different types of habitats you might expect to find in an ecosystem such as a tropical rain forest. How many of these habitats can you include in one EcoColumn construction?
- Put a fruit fly module below a chamber containing a hungry spider or praying mantis. Connect them with a narrow tube which will allow flies to wander upward but which prevents the spider or mantis from descending into the fruit fly chamber. Fruit flies will live off of banana peels and other rotting fruits.
- Plant seeds or small plants in a chamber filled with soil (or filled up to the bottle mouth). In time, root growth will be visible along the clear sides, and from underneath as well. Patterns of root response to crowding, overwatering, and other variables could be compared among different species of plants.

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EcoColumn units are modules made from soda bottle pieces which can stacked to make numerous different models of ecological systems.

Tips

Use the same brand of bottle for all of the EcoColumn units which will make up a final construction. Different brands of bottles can have slightly different diameters or shapes and this can lead to complications. Also, some bottles have bulges at the top of the hip which can make it difficult to stack units. These bottles should be avoided.

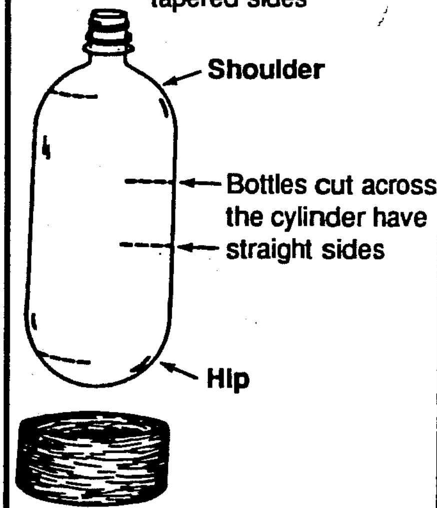
Use a waterproof tape to fix bottle part A to part B. Some clear tapes are waterproof, but check first by taping a test strip to a scrap piece of bottle and leaving it under water overnight.

If the unit is going to contain a terrestrial system be sure to add drip holes in piece A. Units with drip holes high up part A will hold some water and can be used to make a unit which is bog-like in character.

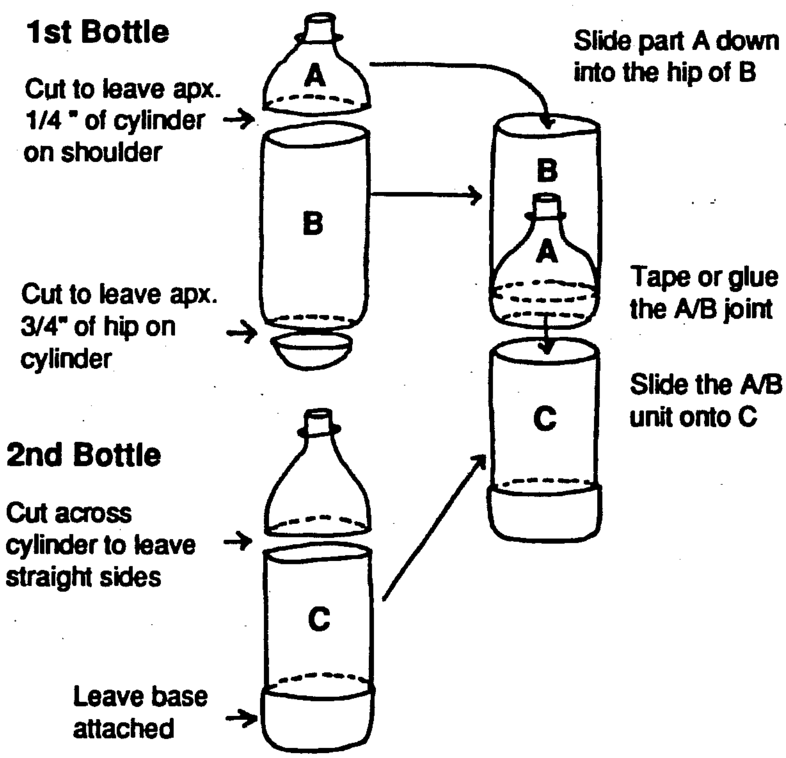
If the EcoColumn unit is going to hold water, seal the A/B joint with a silicone sealant after taping. The sealant also acts as a glue to make a strong joint

Bottle Anatomy

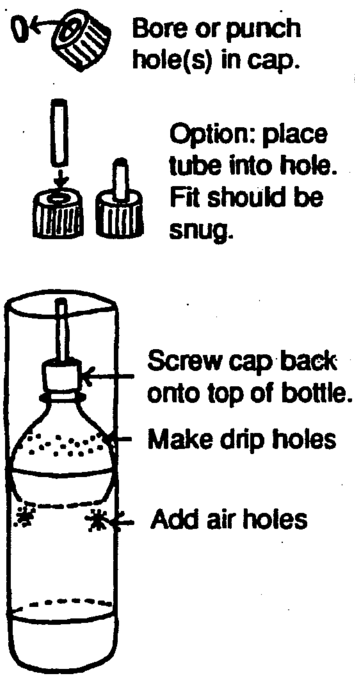
Bottles cut across the <u>shoulder</u> or <u>hip</u> have tapered sides



Cut and Combine Bottles

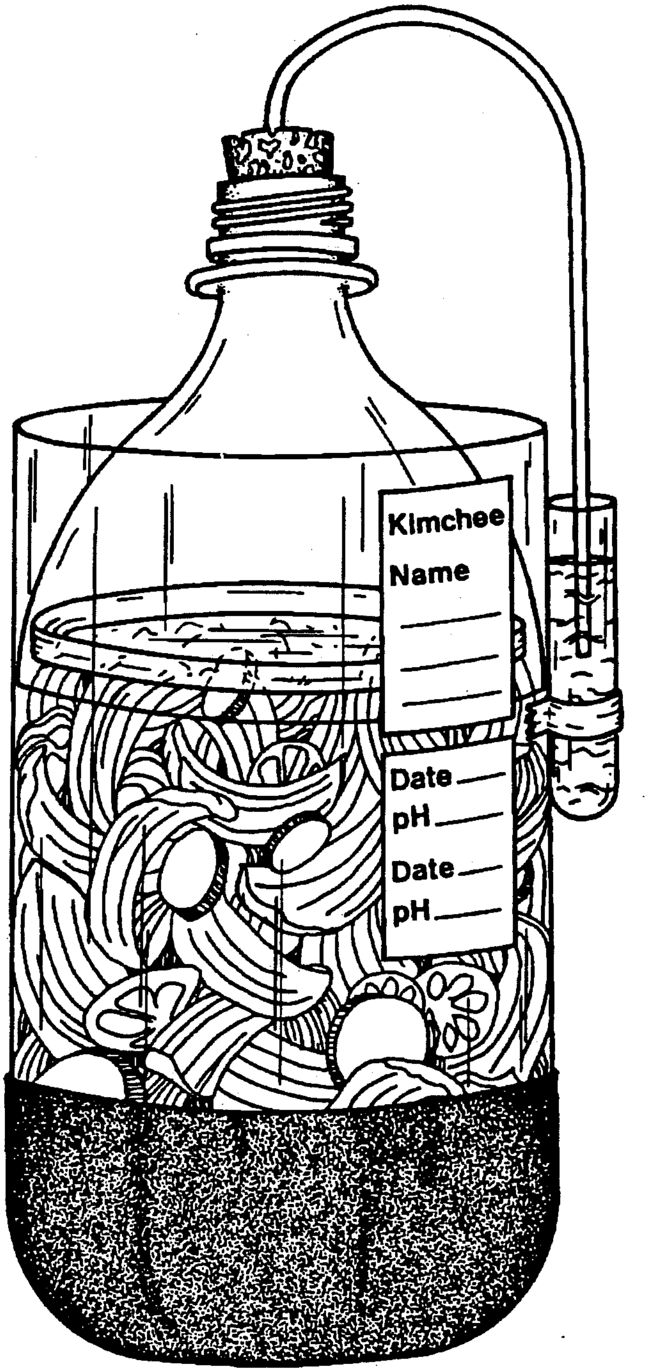


Add Finishing Touches



Kimchee: Korean Delight

Fermentation Experiments with Bottle Biology



Pickling is one of the most ancient forms of preserving food. It involves the microbial conversion of sugars into lactic acid through the growth and activity of acid-forming bacteria known as lactobacilli. As lactobacilli grow, they convert the natural sugars in plant juices into lactic acid. Under the high acidity (= low pH) created by the lactobacilli other food spoiling organisms cannot grow. Lactobacilli are found almost everywhere in our environment and are known as anaerobes because they grow under conditions in which oxygen is lacking. Many foods can be preserved through natural pickling. Some common ones are sauerkraut, yogurt, dill pickles, and silage for livestock. The ancient Chinese cabbage product known as kimchee is a major part of the diet of the Koreans.

You and your students can make kimchee and study lactic acid fermentation in a two liter bottle by using the following recipe and procedure.

Ingredients:

- 1-1$^1/_2$ kg head of Chinese cabbage (*Brassica rapa*; also called napa or petsai), cut leaves into 5-7 cm chunks.
- 1 hot red chili pepper, chopped (or hot chili powder)
- 2 cloves garlic, thinly sliced
- 3 tsp. non-iodized (or pickling) salt

Materials:

- two 2 liter soda bottles
- large plastic lid (approximately 9 cm in diameter) from jar or petri plate
- pH indicator paper (litmus paper, obtainable in small vials from lab suppliers)
- small plastic pipette

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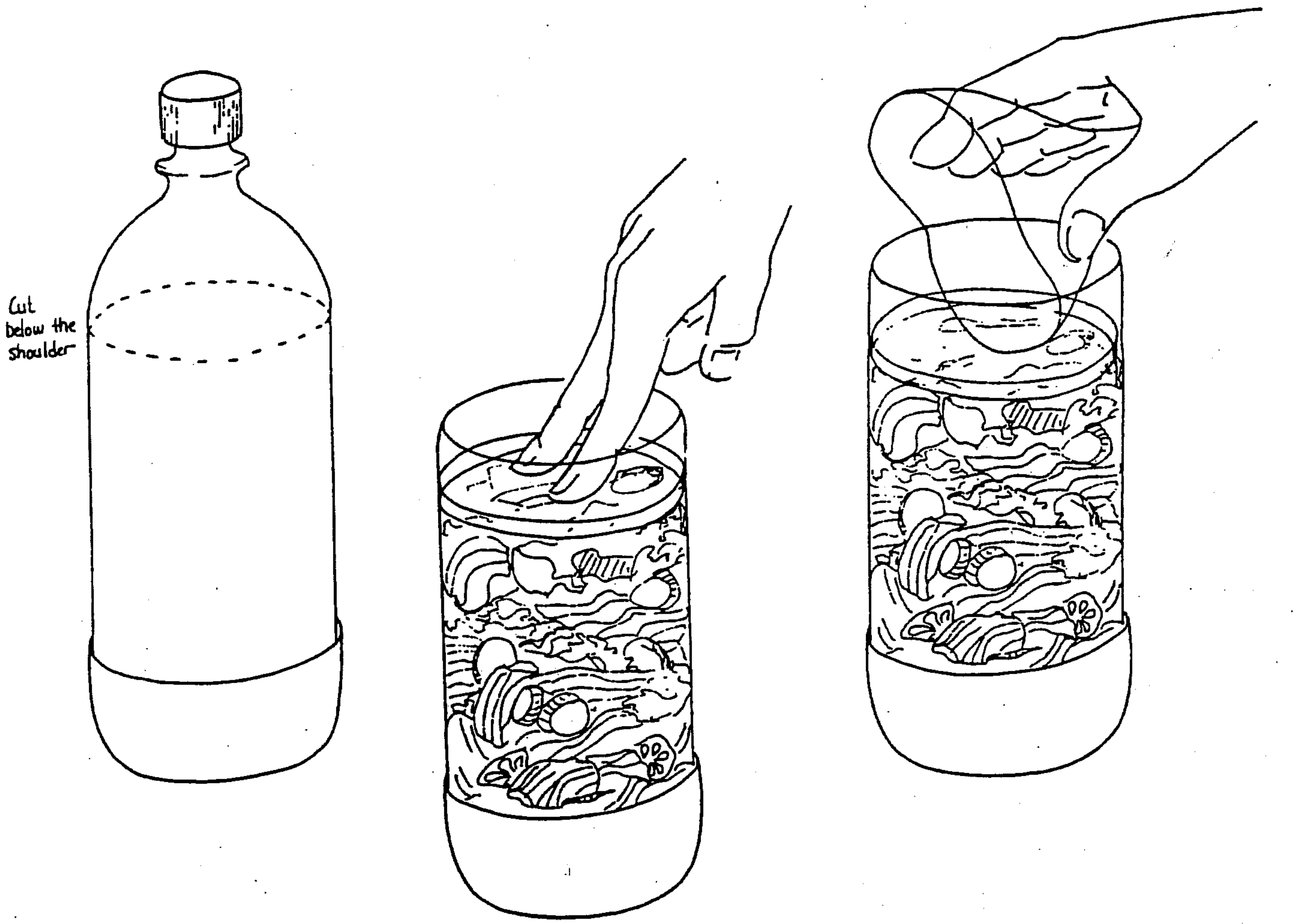


Procedure:

1. Cut the bottle just below the shoulder as shown in the illustration.

2. Alternate layers of cabbage, garlic, pepper and a sprinkling of salt in the soda bottle, pressing each layer down firmly until the bottle is packed full. ***Caution: when working with chili pepper, take care not to touch eyes or mouth. Wash hands thoroughly when finished.***

3. Place the lid, rim side up, on top of ingredients and press down again. NOTE: within a few minutes liquid begins to appear in bottom of bottle as salt draws liquid from the cells of the Chinese cabbage.

4. Press down occasionally for an hour or two. After that there should be sufficient space to fit the lid cut from the second bottle inside the first bottle, forming a sliding seal.

5. Upon pressing firmly with sliding seal, cabbage juice will rise above the petri plate and air will bubble out around the edge of the petri plate.

6. The Chinese cabbage will pack to 2/3 or 1/2 the volume of the bottle. Press daily on the sliding seal to keep the cabbage covered by a layer of juice at all times.

7. Notice bubbles of gas escape each day when pressed. The gas is produced as bacteria grow on the sugary contents of the Chinese cabbage juice in the salty solution.

8. Measure and record the acidity of the fresh juice on top each day with pH indicator paper. Tape the indicator paper on the bottle and write the pH (acidity level) above it.

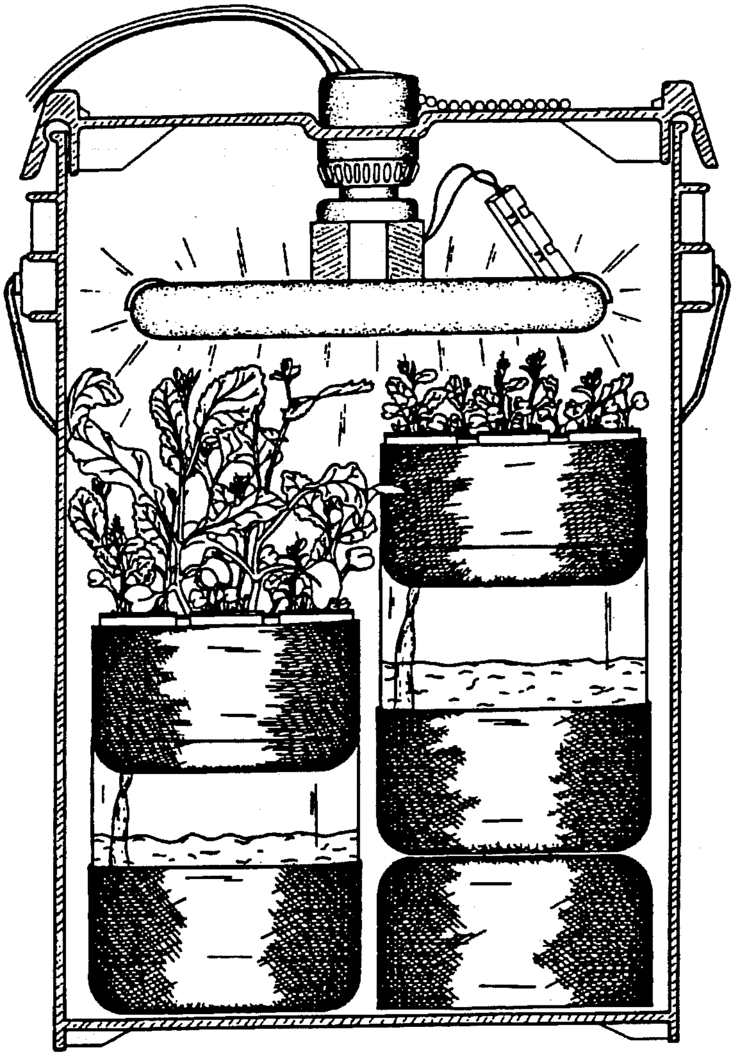
9. Note the increase in turbidity and change in acidity together with the continued production of gas as the pickling proceeds.

Did you notice the aroma of the garlic and pepper? These ingredients flavor the product. After a few days to a week or more (depending on the temperature), the pH will have dropped from 6.5 to about 3.5 and you will have kimchee.

GrowBuckets and Bottle Reservoirs

Plant Growth Systems Made from Recycled Materials

Much of the fun in science comes from creating, designing and running experiments. Over the past year, the Bottle Biology Project and Wisconsin Fast Plants teams have been collaborating in the playful and serious task of designing growing systems for small plants (especially Fast Plants) made out of materials from the trash can. This article presents some of our latest ideas for you to consider and improve upon. What we describe below are working prototypes. We hope that you and your students will modify and improve upon the ideas presented. P.S. Let us know what your ideas and successful designs are!



GrowBuckets

Finding the right light conditions for optimum plant growth can be tricky. Plant researchers sometimes rely on expensive growth chambers to get the right conditions for their experiments. We have recently discovered that the new energy saver circular fluorescent light bulbs fit nicely into five gallon plastic buckets. These bulbs produce, on average, the same amount of light as a 75 watt incandescent bulb, but with less heat production. With several holes cut for ventilation and a door for access, we have been able to grow Fast Plants in these buckets in much the same way we have grown plants under banks of regular 4' florescent bulbs.

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GrowBucket Construction Tips

Cutting Buckets: Five gallon plastic buckets can be cut a number of different ways. If you are making only a few buckets, they can be cut with a heavy duty **utility knife or a key hole saw.** It is frequently easier to start a cut by drilling a hole with either a hand or electric **drill** at the beginning of the line you are going to cut. For production of a many bucket constructions you may prefer to use a small electric hand saw such as a jig or saber saw.

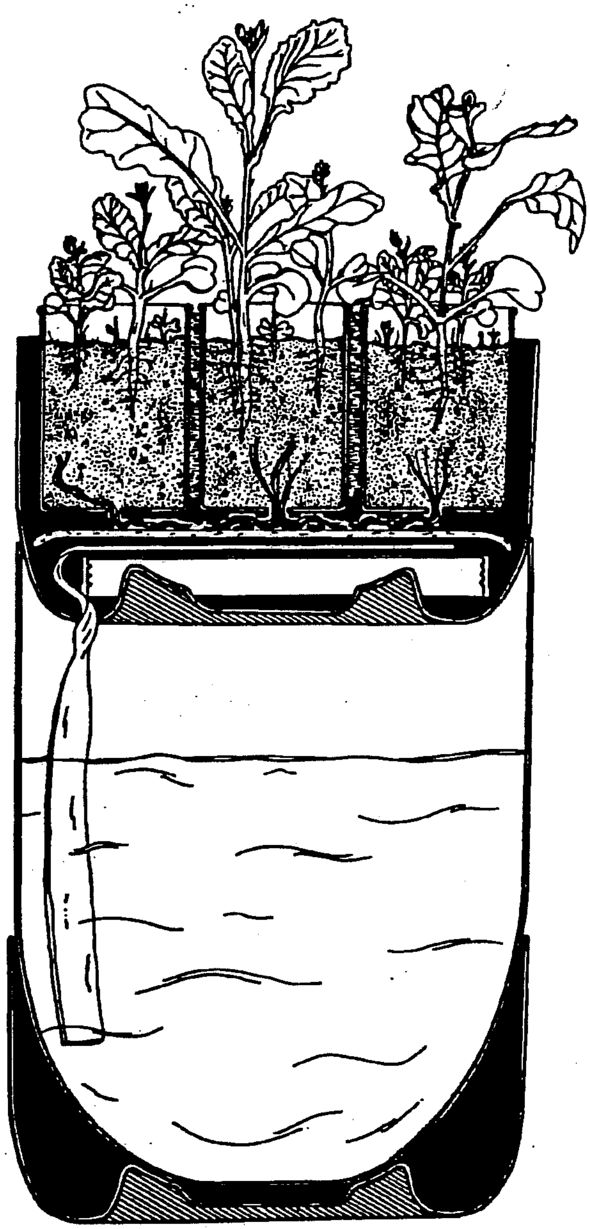
Ventilation: It is critical that the air temperature in the bucket be as close to room temperature (18° to 24° C) as possible. Cut two 7.5 cm diameter holes opposite each other on the bottom of the side of the bucket. Cut another pair of holes opposite each other on either side of the lid. Leave as much space as possible between the ventilation holes on the lid to allow room for mounting the light-bulb.

Mounting the bulb: The **circular fluorescent bulb** is mounted to the lid of the bucket. Cut a hole into the center of the lid which is just big enough to accept the metal shaft of a two piece porcelain utility **light bulb socket**. Connect a light-weight **electrical wire** (lamp cord) with **plug** to the socket. Screw the socket together with the plastic lid sandwiched between the two porcelain pieces. Screw the bulb into the socket. To date we have worked mainly with LIGHTS OF AMERICA 22 watt circular energy saver bulbs. We are in the process of testing similar GE bulbs which are rated at 27 watts.

Making a door: It is possible to access plants in a bucket by removing the bucket lid. However, it is easier to make a door on the side of the bucket. Our doors measure 20 cm wide by 26 cm tall and go to the bottom of the bucket. A hinge can be made from **duct tape** or small metal hinges can be screwed into the plastic bucket wall. Similarly, duct tape can be used to keep the door closed, or a small hook-and-eye can be installed. To allow for the maximum amount of reflected light it is best to keep the door closed when plants are not being moved or viewed.

Positioning plants: When plants are placed in the bucket it is critical that they get as much light as possible. This is especially true for Fast Plants. We recommend that plant containers be propped up until the tops of the plants are two to four centimeters from the bulb.

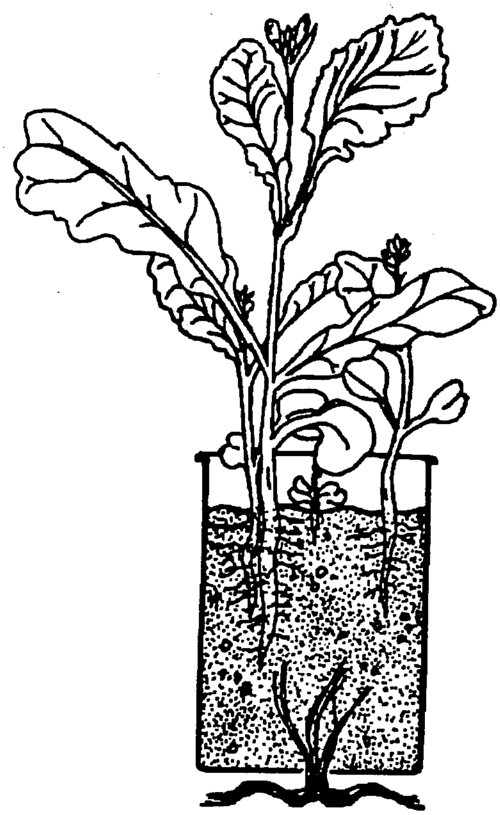
Bottle Reservoirs



Small plants (such as Fast Plants) can be grown in small containers as long as they are watered regularly. This task can be made easier using a continuous water wicking system. In the sample design presented above, empty 35 mm film cans are used as pots and parts from plastic soda bottles serve as water reservoirs. We have found that Fast Plants can be left unattended for two to four days with this system.

Bottle Reservoir Tips

<u>Bottle Preparation:</u> The labels and bases on **plastic soda bottles** can be removed by filling the bottle with hot (50° - 65°C) water. After several seconds the heat sensitive glue will soften allowing the label to be peeled off, and/or the base twisted off. For this construction you will need one bottle with the label removed. Cut the top off of this delabeled bottle. For use in GrowBuckets we usually leave only 4 cm of the side attached to the bottom of the bottle. This makes the reservoir short enough to keep plants in the reservoir from hitting the lid of the bucket. Green bottles, as compared to clear bottles, work well for these reservoirs because they reduce the growth of algae.



You will also need the base from a second bottle. It is possible to substitute certain plastic containers (such as small cottage or cream cheese cups) for soda bottle bases. Place this base, bottom down, into the top opening of the first bottle. Into the base place a **plastic jar lid** (the ones from peanut butter containers are great) or petri dish to act as a platform for the plant pots.

<u>Wicks:</u> **Pellon™**, a fabric interfacing material, functions well as a wick for water. Before being used as a wick, pellon must first be washed on delicate cycle with soap and bleach to remove flame retardants, then line dry. Cut two pieces of pellon wick. The first is a strip 1 cm wide which runs from the bottom of the reservoir through a hole in the upper bottle base and well over the lid platform. The second wick is cut as a disk or square to fit the platform, and is placed over the strip wick on top of the lid. Presaturate the wicks before use by repeatedly squeezing them underwater. Water will move along a wick only if it is presaturated!

<u>Film Can Plant Pots:</u> Empty **35 mm film cans** make wonderful pots for Fast Plants and other small plants (mosses, babies tears, and miniature african violets.). Camera and film development stores discard large quantities of film cans. Ask to have them saved for you! For drainage and wicking, drill or cut a small hole (5 mm) in the center of the bottom of the can.

Thick unpolished **cotton string** (butcher's string for example) cut to about 4 cm in length works well as a wick for these film can pots. Presaturate the string by squeezing it under water. Frequently, a small amount of soap added to the water will facilitate wetting. Push a loop string half way through the hole in the bottom of the can. When the can is placed in the reservoir this cotton string wick should make solid contact with the pellon disk wick on top of the lid/dish.

<u>Fast Plants in Film Cans:</u> A film can has about four times the volume of a single cell in a Fast Plant quad. From this fact it is possible to extrapolate from a Fast Plant manual how to grow Fast Plants in film cans. Four plants can be grown in a film can. N-P-K slow release **fertilizer pellets** can be used at a rate of 12 pellets per can. Fertilization can also be achieved by adding a few milliliters of a one tablespoon/gallon solution of **Peter's fertilizer**, 20-20-20 (N-P-K), to the top of each film can at three, seven, and fourteen days. **Jiffy Mix**, a commercial potting mix, has worked well for us with Fast Plants.

<u>A Word of Wisdom:</u> Through the use of recyclable materials it is possible to make many inexpensive educational materials but, variations in local materials may cause problems. We have found that it is always best to do a test run with any new construction before you use in the classroom or other such situation when first-time success can make-or-break an activity!