The Professor's Garden

The hidden science and mathematics behind nature's beauty

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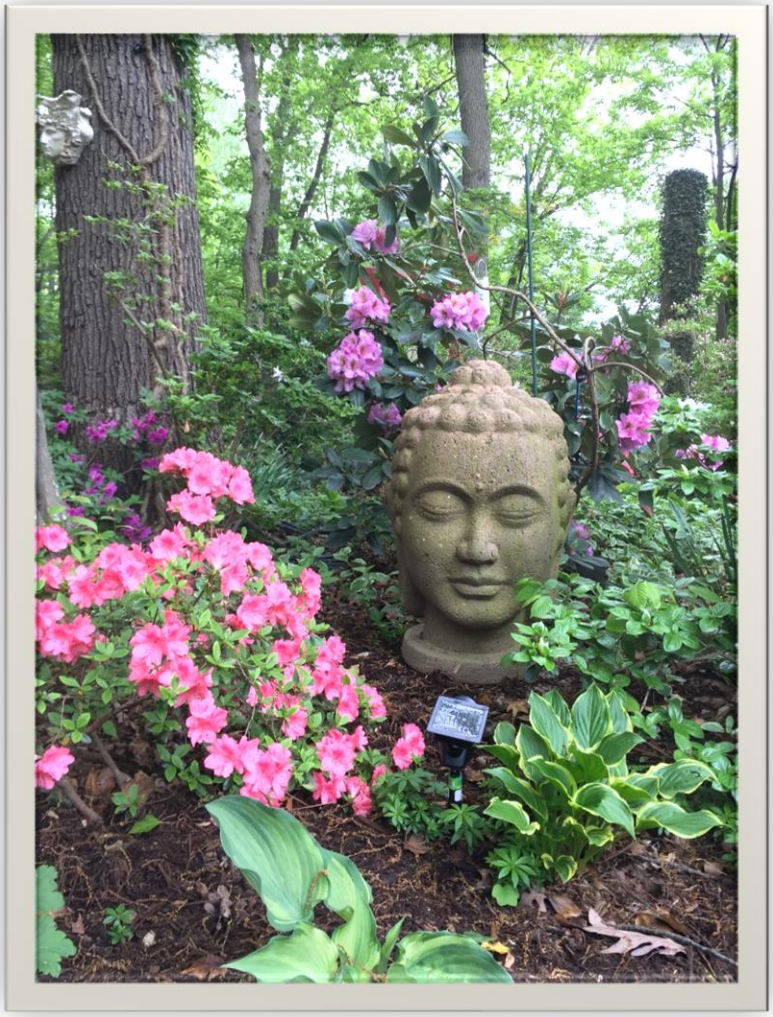

"A garden is a laboratory of nature, a playground for the scientific mind", *Gemini*

This is the story of the transformation of a wild old-growth hardwood forest in Maryland into a serene, Asian-inspired ornamental garden. Emphasizing the integration of science and mathematics with nature's aesthetics, the article details the planning and execution involved in creating the garden. It covers the selection of plants compatible with Maryland's climate, inspired by Japanese and Korean designs, and the strategic incorporation of water features, paths, and a variety of plant species to encourage exploration and tranquility. The narrative also touches on practical challenges such as dealing with local wildlife and the importance of maintaining a balance between natural beauty and scientific principles in gardening.

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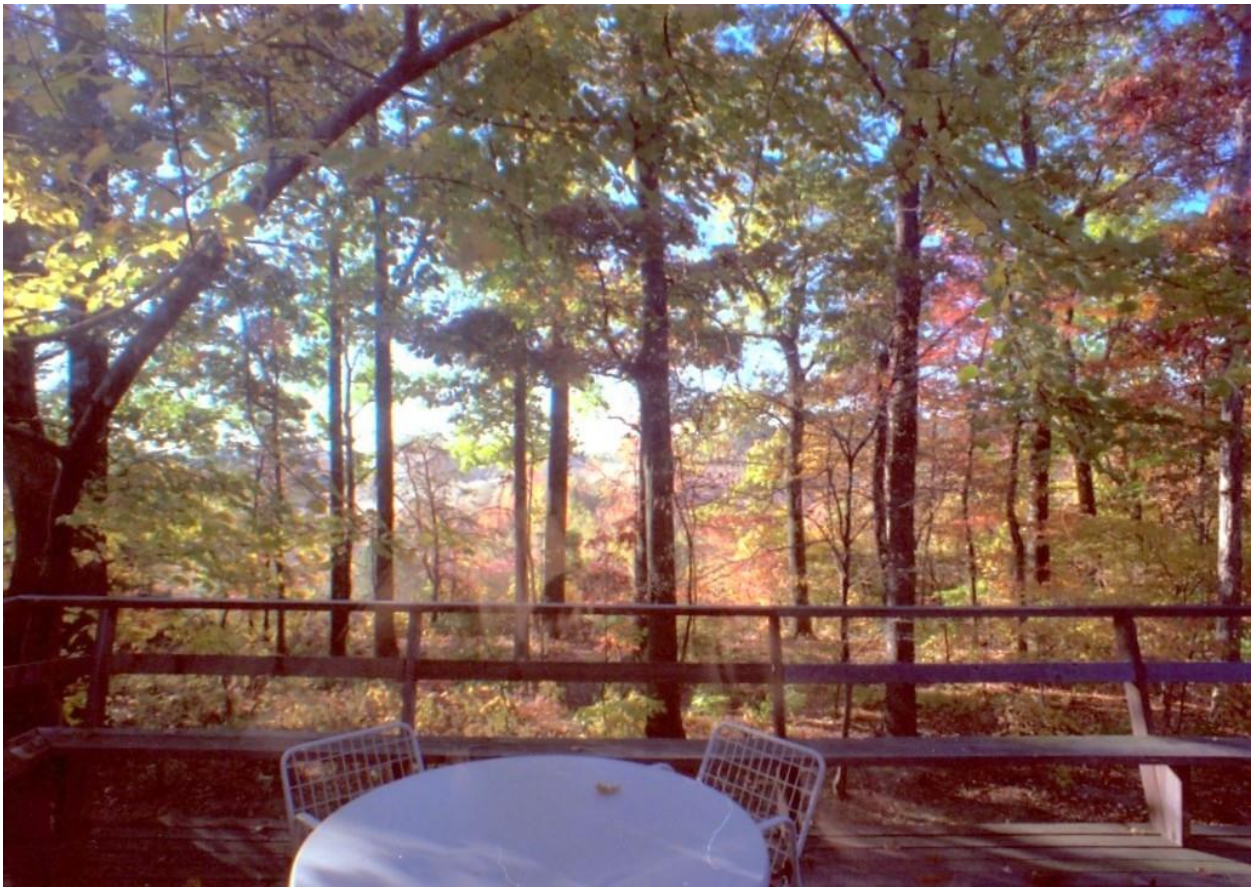
In 1981, my wife and I bought a house in eastern Silver Spring, near Cloverly. The sloping back yard (about 0.3 acres) was a wild old-growth hardwood forest, as shown in this photo. For years it was left unattended, but when we retired in 1999, we thought that it would be a good active retirement hobby to landscape the property into an ornamental shade garden.

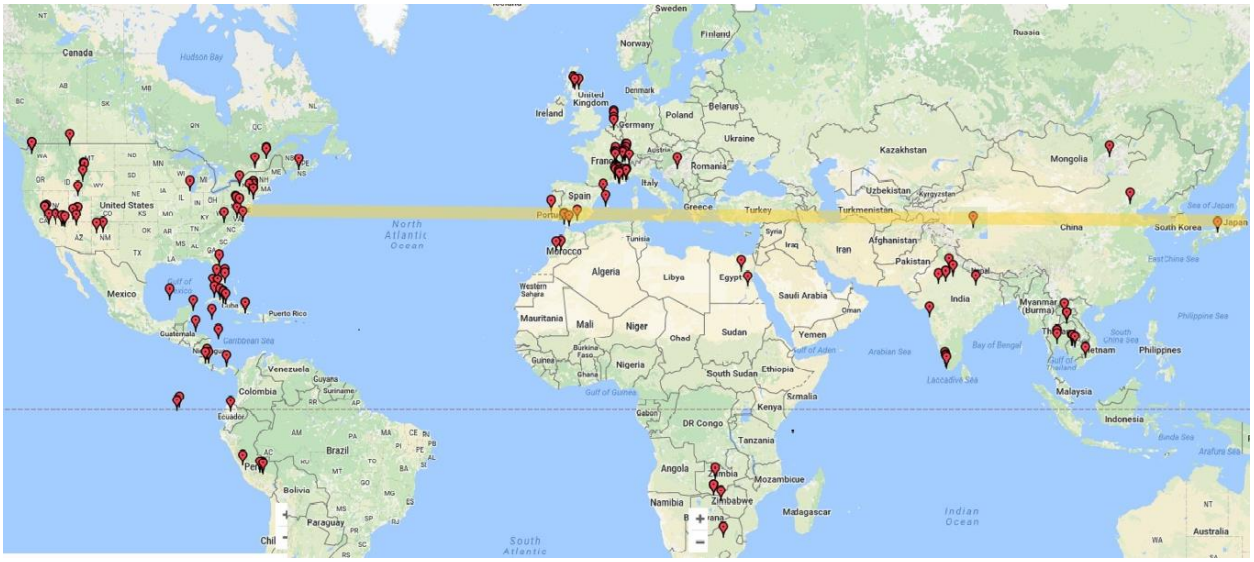


The first step in developing our garden was to learn about the native trees and plants already there, which ones were best for a woodland garden and which ones might be problematic. We had a lot to learn, so we read some books about identifying local mid-Atlantic plants, and I even sat in on a course from the Montgomery College landscape architecture program, given at nearby Brookside Gardens.

Drawing by ChatGPT-4

My wife and I enjoy international travel and have seen many beautiful gardens around the world. We were especially attracted to gardens with an Asian flair, such as the Japanese gardens I had seen on business trips to Japan, as well as Claude Monet's Garden in Giverny, France. Such gardens often have winding paths, water features, natural rock, weathered wood, moss, and Asian decorative features. In these gardens, one typically cannot see the entire garden from one vantage point. The effect is to encourage exploration and inspire tranquility.

Fortunately, many of the beautiful plants and trees that we had seen in Asian gardens can be grown successfully in Maryland. In fact, you can see on the world map below that the horizontal yellow line, marking the latitude of Maryland, passes through central China, Korea, and Japan, suggesting that we might have a generally similar climate.



In 2000, we began the labor-intensive work of clearing the land of undesirable trees and plants, digging out all the poison ivy and greenbrier, and cutting down the silver maples, mulberries, and sassafras trees. The remaining big trees, such as the Oaks, Tupelos, and a Tulip Poplar, were saved to become the backbone of the garden. Along the way we discovered that *many wild native plants and smaller trees were already growing on the property*, sometimes smothered in invasive thorny vines. We found Dogwood, Deer berry, American Hornbeam, Viburnum, Black Eyed Susan, and - most surprising to us- a beautiful species of early-blooming azalea, called a Piedmont Azalea, that is native to this area.

Garden development

We did not have a master plan for our garden. Rather, it developed organically, one section at a time, with lots of learning by trial and error, ultimately influenced by gardens that my wife and I had seen on our travels

An early project was to deal with the slope. The property is on a gently sloping south-facing hillside. Some garden features would require level ground, such as seating areas, ponds, and structures such as a greenhouse. So, we began to regrade the property into level areas connected by a network of gently sloping paths, starting in one corner and gradually expanding the path network over the next few years.

It didn’t take us long to learn that dirt paths, covered with leaves or with wood chips, would become muddy and eroded after heavy rains. Poured concrete walkways would be too expensive and wouldn’t look right for a woodland garden. We decided instead to cover the paths with crushed brown stone, or in some areas with grey round river rock, on top of landscape fabric. The crushed stone has several advantages: it bears weight well underfoot, won’t wash away in heavy rains, is available in bags at a local garden center, and it allows for the possibility of changing the paths, for example widening, re-directing or re-grading them as desired.

All the while we collected and planted shade-tolerant hardy plants that would form the backbone of the garden, with an emphasis on those that are of Japanese or Korean origin. These included Japanese Maples, Painted Fern, Rhododendron, Hosta, Toad Lily, Japanese Andromeda, Fountain Grass, Bamboo, Nandina, and Kousa Dogwood.

Garden construction

Our first construction project, in 2001, was to install a small goldfish pond on a level area near the house, with a natural flagstone patio and benches. We added a small fountain and a filter to help keep the water clean, and Mary arranged some flowering plants around the pond to give it a more natural look.

Overlooking that pond, we set up a so-called “outdoor room” adjacent to the back of the house, with comfortable seating, lighting, and cover for sun or rain.

Another early project was the construction of this greenhouse, which we made from a mail-order kit in 2005. (It was delivered in many separate parts that were light enough that we could carry them from the driveway down to the back corner of the garden). We use it for dividing and potting plants and for storing garden implements and materials, but not so much for starting seedlings.

Because of the hillside slope, it was often necessary to construct low retaining walls separating the planting beds from the paths. There are several ways to do this, depending on the height of the wall. In different parts of our garden, we used wooden railroad crossties, landscape timbers, found rocks (dug up from the garden when digging planting holes), and stacked slate. Crossties and timbers are less expensive than purchased slate, but they have a limited lifetime.

In 2004, we installed another pond in the lower back corner of the garden. That required moving soil to make a a large level area, constructing a retaining wall for the patio area, digging a big hole for the pond, and removing the rocks and tree roots. We lined the hole with a pad and rubberized pool liner and covered the edges with small boulders and river rocks that we purchased from a local landscape firm.

After I compacted the soil in the adjacent patio area, my wife Mary fitted the flagstones together over a layer of paver base and coarse sand. This results in a stable weatherproof base for furniture that retains a natural look. Behind that, we planted a stand of bamboo in large tubs, for a traditional Asian touch.

The only landscaping that had been done by the previous owners of our house was a large level area near the house, with a 2-foot-high retaining wall made of stacked wooden railroad crossties. The crossties are protected against rot using creosote, a tar-like substance derived from coal and petroleum. With proper treatment, crossties so treated are claimed to last about 40 years.

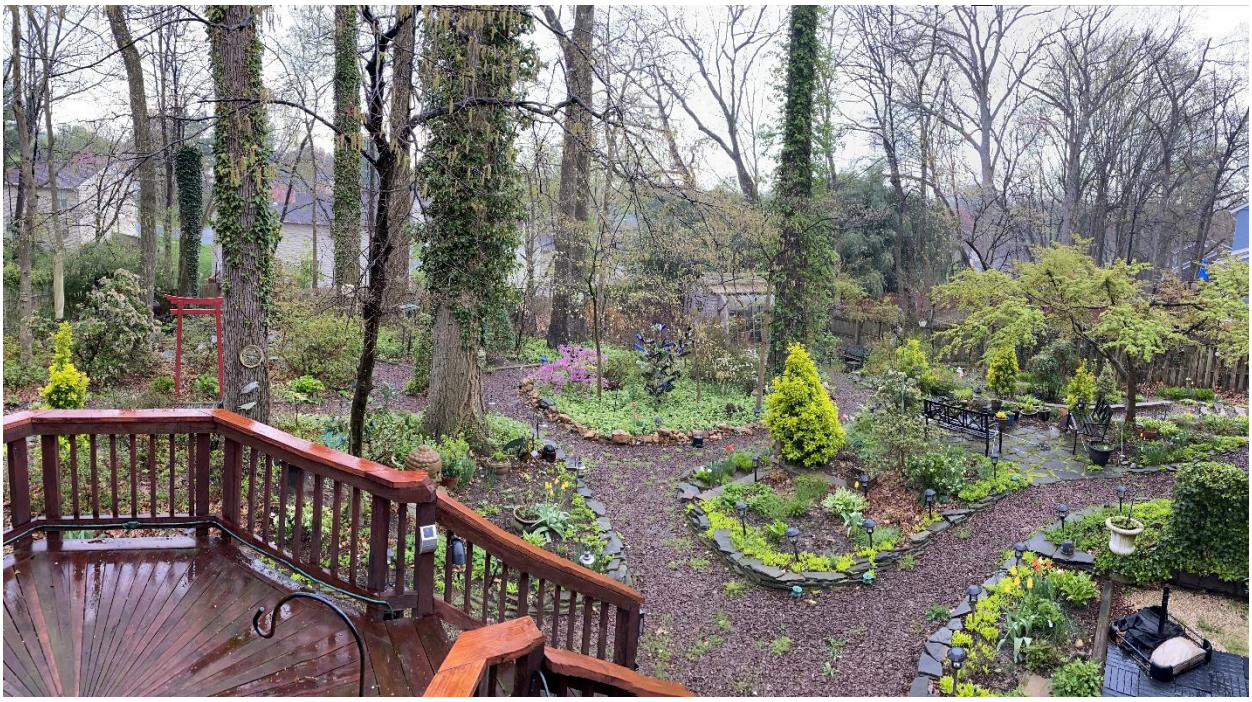
And sure enough, in 2015, just about 40 years after their initial construction, the crossties began to decay and the wall began to sink and slump several inches, as indicated by the level line in this photo. There was a danger that the whole wall might collapse. So, we dug out all the crossties…

… and replaced them with “split face” stone blocks - about 40 pounds each - at the height of the original wall. Split face blocks are factory-made blocks that are flat on 5 sides, for easy stacking, but with a random stone finish on the front facing side. This results in a more natural-looking outward surface. These were dry-stacked, for better drainage, and reinforced with vertical rebars in the interior cells that were filled with concrete mix.

Garden paths

We wanted the various planting areas of the garden to be connected by a network of steppingstones and sloping paths, avoiding steps as much as possible so it will be easier for carts and wheelbarrows. Fortunately, the driveway is nearly the highest point on the property, so that when we unload heavy materials for garden construction, they can easily be moved on carts to most parts of the garden on the sloping paths. We created paths that curve and disappear around corners, like this one in the front of the house, because they draw attention to what lies beyond.

This photo, taken in the main garden area in early spring before the trees have leafed out, shows some of the path network, but much of it is obscured by trees and bushes.



Here, in the same photo, all the paths are marked up, showing even those in the background that are not clearly visible. The paths form a series of “switchbacks” to make it easier to move carts and wheelbarrows up and down the slope. Mary and I did all this work ourselves, one section at a time, over a span of 20 years.

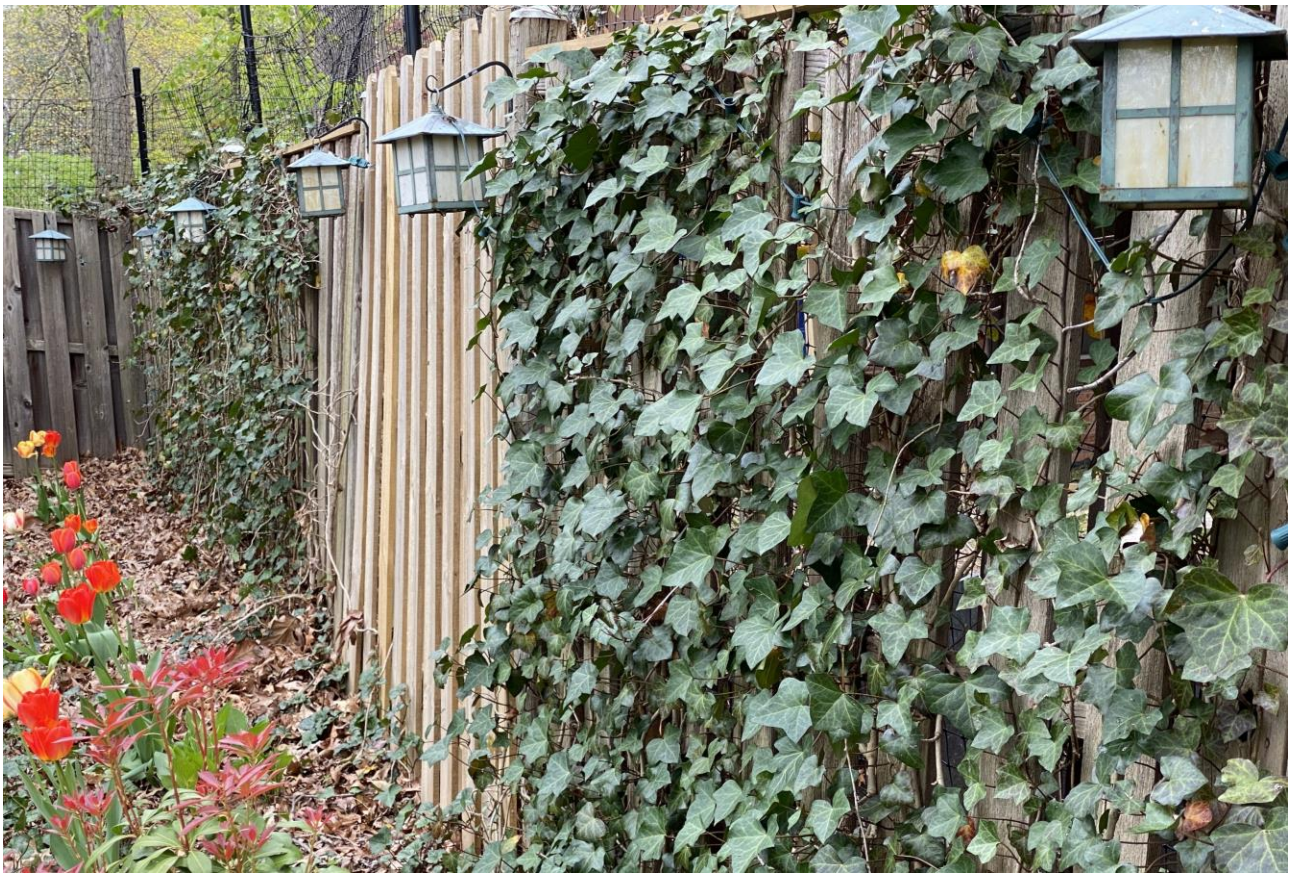
Cultural elements

We have added some Asian cultural elements, including a Buddha head and a pagoda, both bought from garden centers, a torii that I built from plans found on the internet, a gong brought back from a trip to Thailand, and a pergola built from a kit that we purchased online.

We have added decorative faces throughout the garden that we have collected on our travels. We usually place them on trees near the paths.

Exterior electricity

We have installed exterior electricity with outlets throughout the garden to power the decorative lighting, pumps, fountains, Bluetooth speakers, security cameras, and the greenhouse. 115-volt lines are run through waterproof underground conduits for safety. We have used GFCI (Ground Fault Circuit Interrupter) power outlets, designed to protect people from electrical shock. They do so by instantly shutting off power if it detects a ground fault or leakage of electrical current outside of the normal path.



In 2020 during Covid, we purchased a kit to build a pergola, which contained 75 pre-cut wood pieces. We painted each piece with preservative stain and bolted them together with the supplied hardware, following the pictorial instructions. We placed it on the flagstone patio beside the lower pond.

What to do about the deer?

White-tailed deer are plentiful in Maryland and love woodland gardens, especially Hosta, which they will eat right down to the ground. To keep them out of the main garden, we had a deer fence installed around the entire back garden, based on a recommendation from Brookside Gardens. It's designed to be inconspicuous, but if you look closely, you can just see it in the photo on the left. The deer seem to prefer the early morning hours, when they show up in great numbers. Here, they seem to be grazing on acorns that are dropped by our huge oak trees.

Outside the fence, we emphasize plants that the deer don’t like, such as Butterfly bush, Hellebore, Daffodils, and Peony.

Botany and plant selection

Plants in ornamental gardens can be classified into several types. Perennials, annuals, and woody plants of two types: deciduous and evergreen. Perennials die back to the ground in the winter, but the roots remain alive to emerge next spring. Annuals die completely and must be replaced each year. Woody plants retain their stems and branches all year; in the winter, the deciduous ones lose their leaves and evergreen ones keep them.

Perennial flowers typically bloom only at specific times throughout the season, so that the look of the garden changes continually throughout the year. Here are, left to right, top to bottom, Lamium, azalea, toad lily, daylily, obedient plant, oriental lily, nandina, dogwood, hydrangea, Siberian iris, periwinkle, primrose, rhododendron, hellebore, and piedmont azalea.

Here are epimedium, bleeding heart, heuchera, yellow archangel, tulips, astilbe, crepe myrtle. Most are perennials, but dogwood, hydrangea, nandina, and crepe myrtle are deciduous woody plants, and rhododendron and most azaleas are evergreen, except the piedmont azalea, which is deciduous. All these are reliable plants in our region and return year after year.

We also use annuals, especially impatiens, to provide season-long color even when the permanent plants are not flowering.







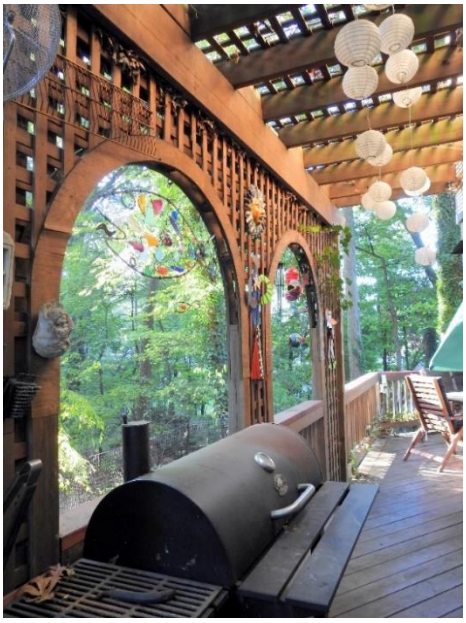
The garden at night

Exterior lighting is used throughout the garden, allowing it to be used after dark and resulting in a striking look in the evenings. There are path lights, spot lights, and string lights.

We use a combination of low-voltage AC-powered LEDs and solar lights. As the daylight dims, photocell controllers turn on groups of lights automatically one by one, and then turn them back off again after a set number of hours or when their batteries are exhausted.

Outdoor dining

A large two-level deck overlooks the garden, with lots of annual flowers in hanging pots. The main level is one story above garden level. (We find that there are fewer mosquitoes at that level, because mosquitoes tend to stay close to the ground-level water sources where they hatch). We have placed an outdoor dining table just outside the kitchen, where it has a nice view of the garden. A drop-down shelf serves as a convenient pass-through to the kitchen. Also on that level is a BBQ grill, just outside the kitchen sliding doors, which is especially convenient when we want to grill in bad weather.



Our deck and garden have become a regular gathering spot for friends, family, and neighbors. Neighborhood kids like to run around the paths, have scavenger hunts, play hide and seek, and feed the goldfish, while the grownups socialize.

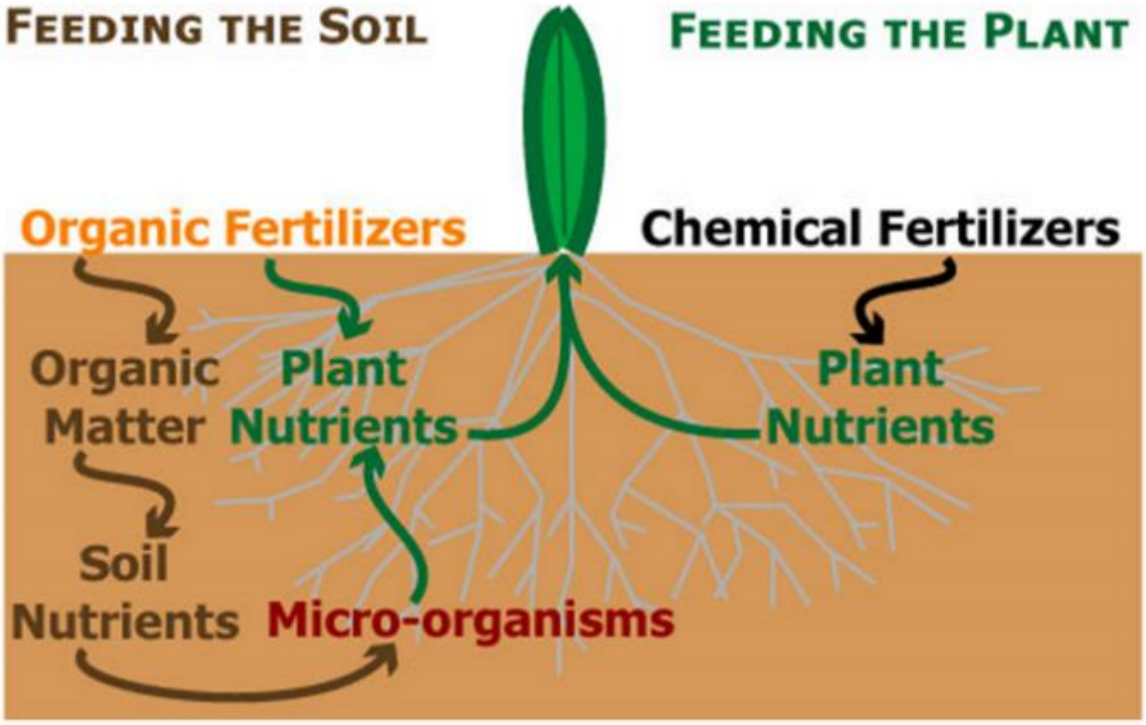
Garden maintenance

Compost: Putting microorganisms and fungi to work

In the back corner of the garden, we keep a large compost pile divided into two sections. This works over a two-year cycle. The raw material goes into the first section; this includes all plant clippings, fallen leaves, finished annuals, and all kitchen scraps except meat and citrus. We water it in dry periods and add a shovel-full of “ten-ten-ten” fertilizer once a year to feed the microorganisms and fungi that do the work.

Sometime in the middle of the summer, we move all that material over to the other side - the top layer first, so the whole thing is inverted. It continues to decay all through the next fall and winter. All new material then goes into the now-empty left-hand side. The next spring, the compost on the right side will be finished and ready to be harvested. By the next summer, once all the finished compost on the right is used, the cycle begins again. Most everything is reduced to black crumbly compost after that two-year cycle. (Anything that is not completely composted is tossed back into the left-hand side). The finished compost is spread on the beds throughout the garden or stored in tubs.

Adding compost to the soil improves its structure, adds organic matter, and supplies needed *micronutrients*, whereas inorganic "ten-ten-ten" fertilizer just adds the required *macro* nutrients and does nothing for the soil structure. Over time, the inorganic fertilizer added to the garden is converted to *organic* material by plant growth. Eventually, all the plant clippings, fallen leaves, cut-down perennials and finished annuals are placed in the compost pile and are decomposed and returned to the soil after two years. In this way, the garden acts as an *inorganic-to-organic conversion system*.



Humus (not the same as hummus)

Compost returned to the soil eventually decomposes into *humus*, which is a dark, nutrient-rich, stable material that is resistant to further decomposition. It's a crucial component of healthy soil, contributing significantly to its fertility and structure. Chemically, humus consists of long-chain cross-linked polymers. Most of the carbon in plant vegetative matter comes from photosynthesis, using carbon dioxide soaked up from the air. As long as you don't burn it, the carbon remains trapped in the plants and in the soil. As a stable form of carbon, humus thus plays a role in *carbon sequestration*.

What about the weeds?

One question that many visitors to our garden ask is how do we keep ahead of the weeds? The answer is: a combination of

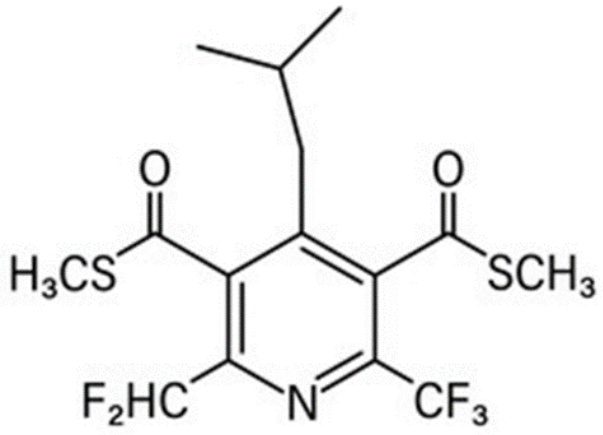
(a) applying a nice layer of mulch to the beds each spring,

(b) planting groundcovers such as Lamium, Pachysandra, and ivy in some areas,

(c) using a pre-emergent weed preventer like *Preen*, and

(d) hand-pulling the few weeds that escape those measures.

A pre-emergent weed preventer works chemically, not by killing growing weeds, but rather by *preventing weed seeds from germinating* by disrupting key biological processes in the germinating seedlings. This is effective only for *annual* weeds that die each winter and grow back from seeds left in the soil. It does not work for perennial weeds whose roots survive the winters, such as dandelion and wild onion. Those weeds can be controlled by spot spraying with a selective weed killer such as *Weed-B-Gon*, which will not harm grasses.

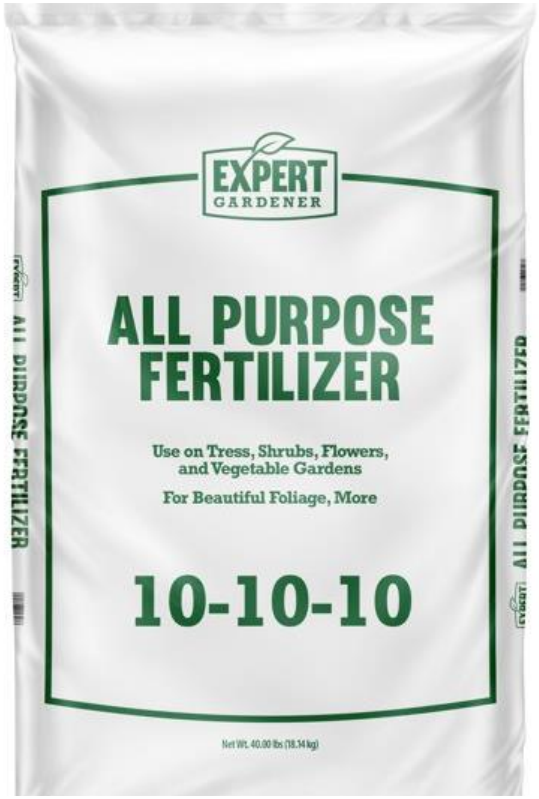


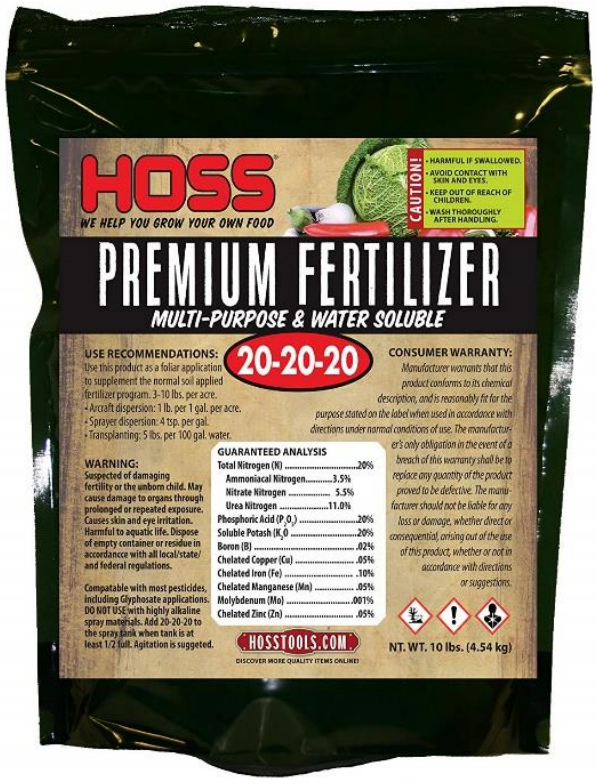
Unfortunately, pre-emergent germination suppressors also interfere with the reproduction of biennial plants, such as forget-me-not, delphinium, hollyhock, Canterbury Bells, and foxglove. Biennial plants have a two-year life cycle. The first year after growing from seed, they do not bloom. After that growth winters over, the plants bloom the next year, and those blooms make seeds that fall to the soil and germinate, starting the process all over. Because of that dependence on continual regrowth from seed, you can't use a germination suppressor like Preen in areas where biennials grow.

Each year in the spring, we apply a 1 inch layer of shredded hardwood mulch to the beds, which helps to retain moisture and to suppress weeds. The mulch eventually decays into the soil over time, improving its structure and adding organic matter. This takes about 30-40 bags of mulch.

Fertilizing the garden

To keep all these beautiful flowering plants healthy and growing, we apply a light application of a general-purpose inorganic “10-10-10” fertilizer to all plants once a year. Fertilizers are labeled by their “N-P-K” numbers, which represent the percentage of Nitrogen (N), Phosphorus (P) and Potassium (K). Those are the so-called “macro-nutrients”, the three *elements most needed by plants* and thus the ones that are *most quickly depleted* in soils by growing plants. Nitrogen promotes **leaf** and **stem** growth. Phosphorus and potassium support **root** development, **flower** and **fruit** production.





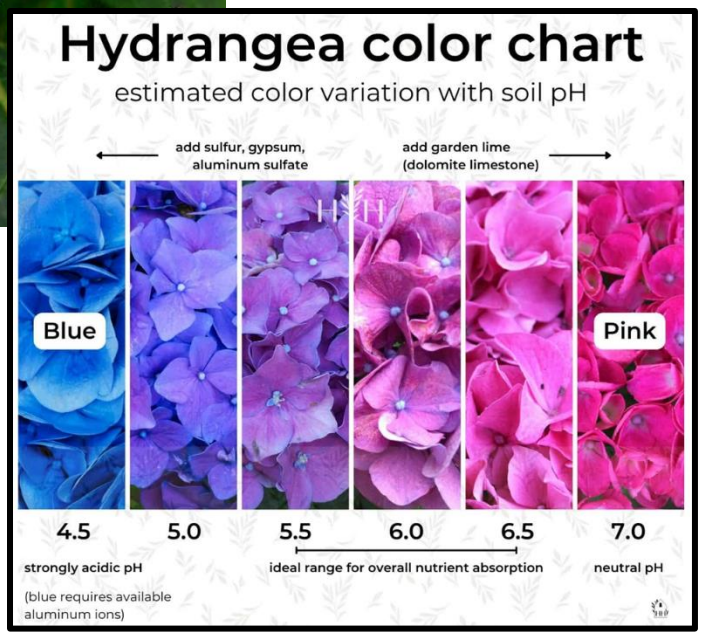
To the lawn in front of the house, we want *leaf growth* specifically, and not flower and fruit production, so we apply a *high-nitrogen* fertilizer once a year. We use a battery-powered hand-held spreader to insure even distribution.

Soil pH

Northeastern states often have acidic soil, particularly in forested areas. Plants favoring slightly acidic soils include rhododendrons and azaleas, blueberry bushes, camellias, pine trees, and magnolias, which therefore often do well in our area. Simple soil pH testers are sold at many garden centers.

The colors of hydrangea blooms are particularly susceptible to soil pH: neutral or alkaline soils result in pink bloom, whereas distinctly acid soils result in blue blooms. You can apply limestone to the soil to make it more alkaline and aluminum sulphate to make it more acid. Both are available in gardens centers.

"Blue Billows" hydrangea



Pollinators and other garden visitors

Our garden has had many animal visitors, mostly welcome, including butterflies, bees, spiders, many kinds of songbirds, as well as squirrels, chipmunks, foxes, frogs, terrapins, and voles. The spider here is an Orb Weaver, one of the good spiders, which eats flies and mosquitoes, so he is welcome. We minimize the use of insecticide in our garden, so as not to harm the pollinators and beneficial insects. But we do occasionally use a fungicide spray to control outbreaks of fungus infection, particularly on Hosta.

We do want to encourage songbirds, so we have added bird houses, feeders, water features, and birdbaths. Here we show a pileated woodpecker sitting on our deck railing, four blue robin eggs, and a birdhouse made from a gourd.

To discourage the squirrels from gobbling up all the birdseed in the feeders, we use bird seed coated with cayenne pepper, which contains a chemical called *capsaicin* whose fiery hot taste discourages the squirrels but cannot be tasted by birds.

Frogs and toads are strong indicator species for pollution. They have permeable skin through which they absorb not only *oxygen*, but also any *toxins* that might be around. I'm happy to see that frogs are always hanging around our ponds, as in this photo.

It's interesting that, just a week or two after filling our first pond, the frogs began to show up, sitting on the rock surrounding the ponds. How did they know we had just built a pond?

This particular frog is, not surprisingly, a **Green Frog** (*Lithobates clamitans*), which is commonly found in the eastern United States.

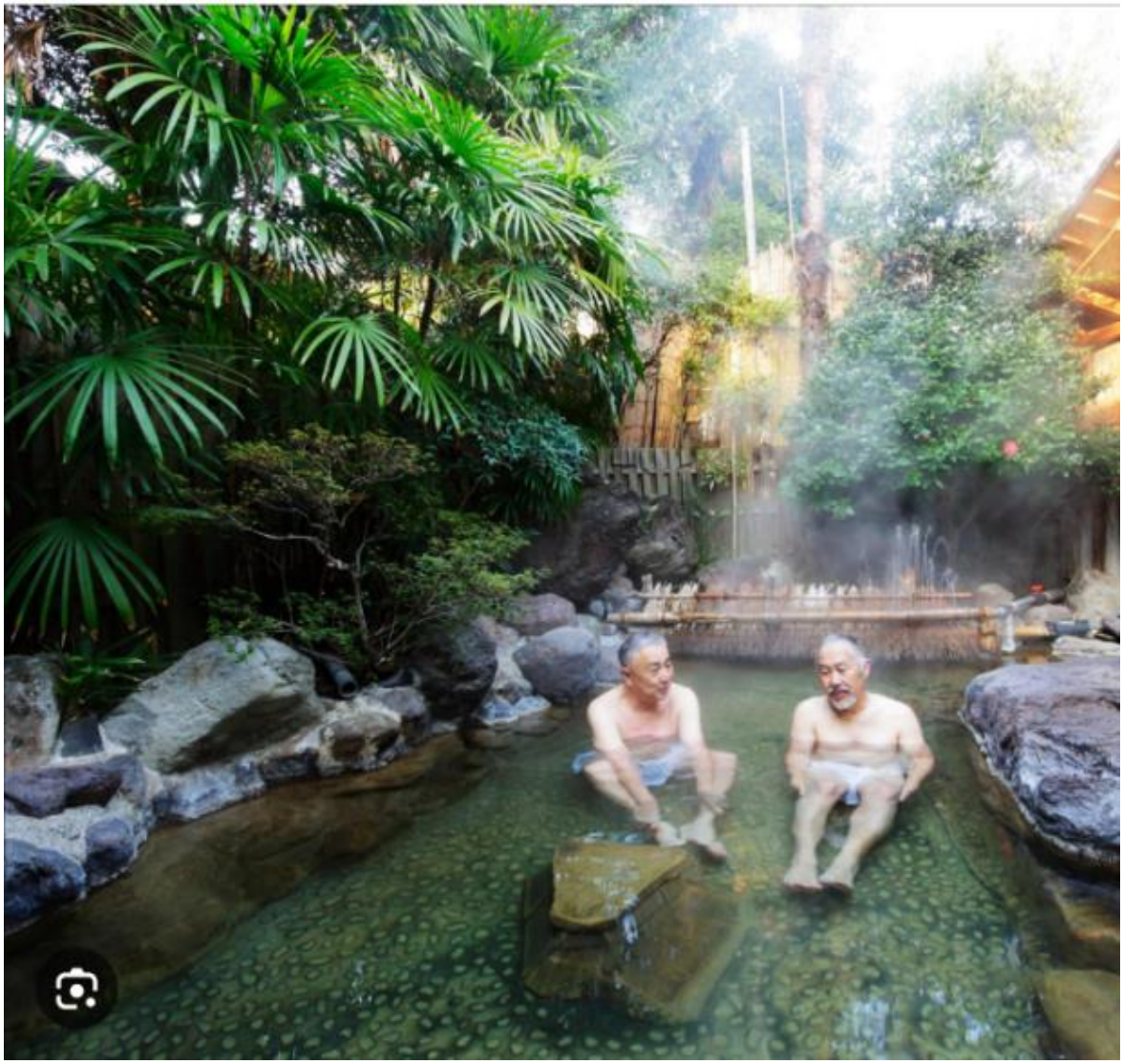
Some of our trees and perennial plants also serve as *natural* food sources for wildlife, especially in the fall when they produce their fruits and seeds, such as Viburnum, Virginia creeper, Hornbeam, Dogwood, Acorns, and Oregon grape-holly.

Ponds and other water features

To keep the water in the ponds aerated and to reduce the mosquitoes, we keep the water moving. This waterfall is created by an underwater pump that sucks up the pond water, filters it, and dumps it over the moss-covered rocks. We also place “mosquito dunks” in the ponds each month. These are small floating pucks that contain a bacillus called “Bti”, a naturally occurring bacterium found in soil. It specifically targets mosquito larvae, as well as the larvae of some other insects like black flies and fungus gnats, without harming other wildlife.

The moss on the rocks does not have to be planted; it just shows up all by itself in areas that remain moist over time.

In Japan, natural geothermal hot spring baths like the one shown here, called “onsens”, are highly prized. My wife and I have enjoyed the geothermal hot springs that have become popular tourist attractions in Iceland (The Blue Lagoon) and at Las Lagos in Costa Rica.

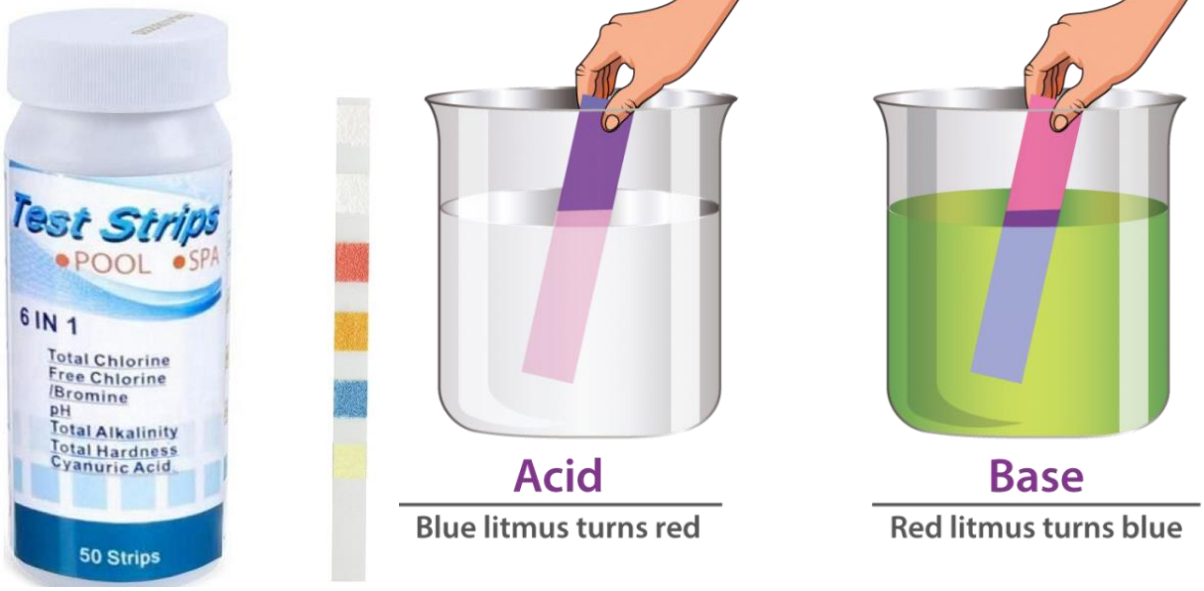


To give ourselves the possibility of relaxing in a steaming spa in our own garden, we added a hot tub, which we placed with a view of the garden, close to the basement walk-out sliding doors. It's powered by a dedicated 115-volt circuit. Spas like this need regular attention to remove bacteria, algae, dead skin cells, and body oils from the spa water. A clean hot tub prevents skin irritations and makes long soaks more comfortable. (This is not an issue with natural thermal baths such as onsens, because the water in natural springs is continuously refreshed).

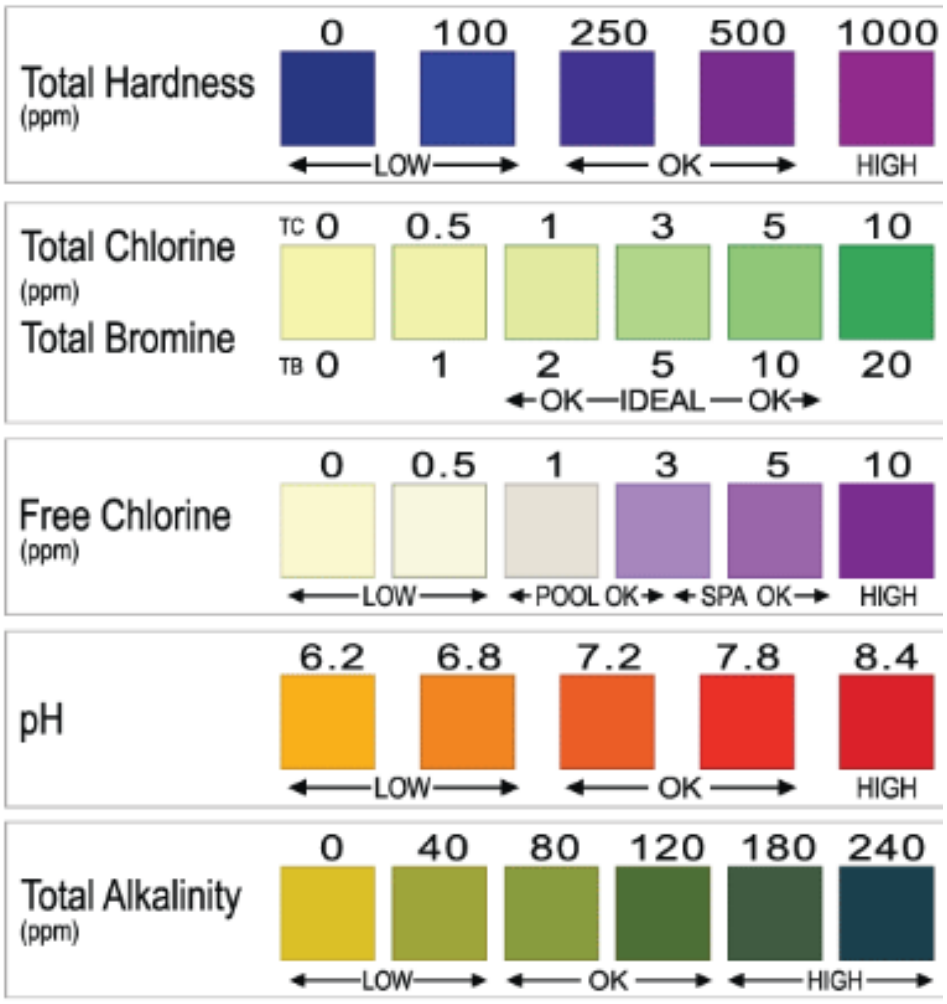
Spa chemistry

To keep the water safe and clear, chorine is added to the spa water in the form of tablets or granules containing a sodium salt of hypochlorous acid (NaOCl).

Test strips are an easy way to test spa water quality. These are paper strips with several square segments, each impregnated with a different indicator chemical that reacts with a specific species in the water to produce a range of shades of color depending on the concentration of that species. You simply dip the strip in the water and compare it to the chart. You might be familiar with litmus paper, used a test for acidity or alkalinity.



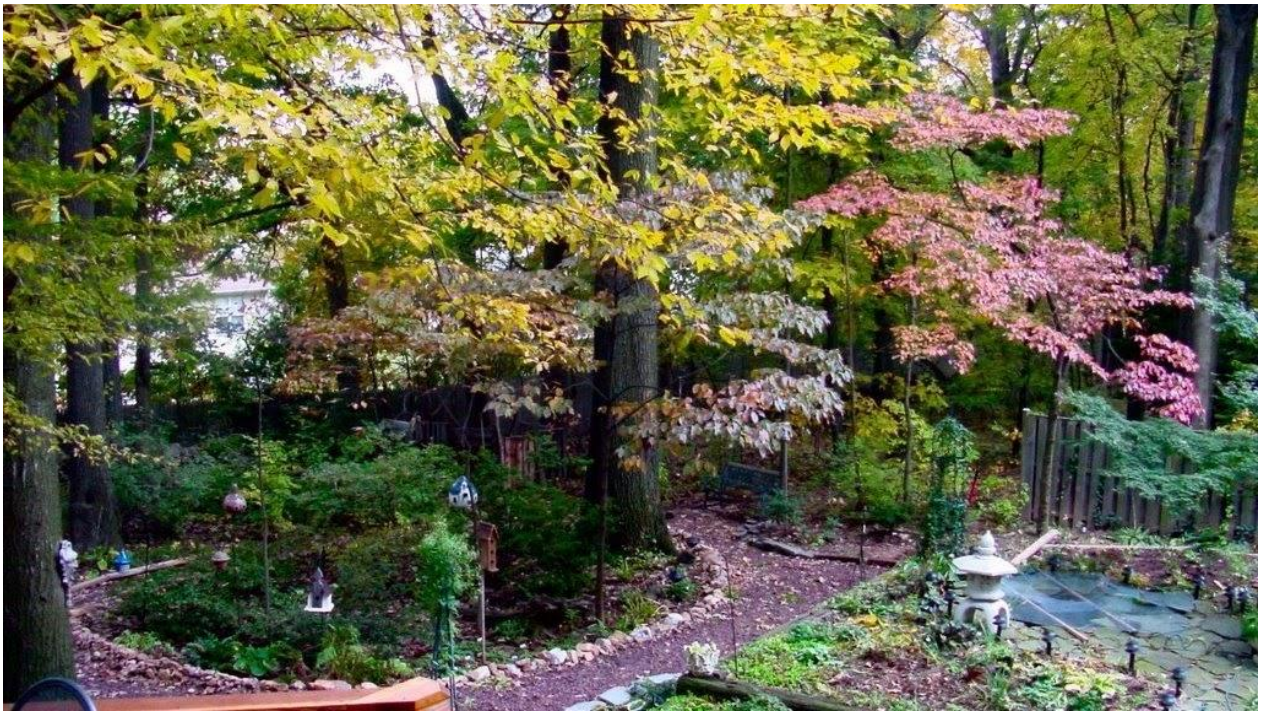
But for pools and spas, a single multi-segment test strip measures water hardness, chlorine, pH, and alkalinity. For each, the ideal range is indicated on the accompanying chart by the “OK”. The pH, for example, should ideally be around 7.4. Why? Because eye mucous membranes are that pH and water that pH won’t burn the eyes. Also, that pH is best for preventing corrosion of the pumps and pipes and other pool parts. But of all those tests, the chlorine concentration is the most important, and keeping it in the OK range will optimize its disinfectant properties.



To correct chemical imbalances, you can purchase sets of chemicals that are conveniently bottled and labeled for adjusting pH, chlorine, and alkalinity. They come with easy instructions.

Preparing for winter

As winter approaches, we begin to cut down the fading perennials and dying annuals. By the time we are ready to leave for our winter lodgings, we have cut down all perennials to the ground and have added that material to the compost pile, along with whatever leaves have fallen by then.



The fact that the garden goes mostly dormant in the winter makes it possible for us to enjoy spending that time in warmer climates while the garden sleeps. Before we leave for the winter, we cover the ponds with a tough polymer mesh that keeps out fallen leaves and discourages the racoons, foxes, and hawks that are prone to feasting on the goldfish.

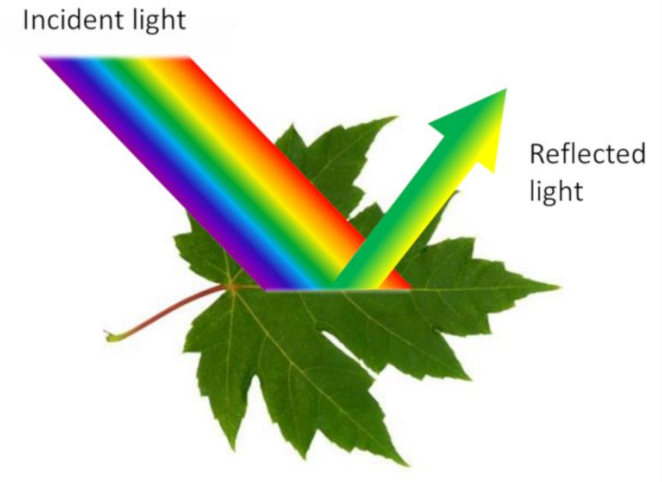
Goldfish are cold-blooded and are not very active in cold weather. They survive the winters just fine, even if they are not fed. All winter long we have air bubblers running in the ponds, like those in indoor aquarium tanks, to aerate the water and remove toxic gases like ammonia. Baby goldfish cost about $0.25 each, and sometimes they live for several years, enough to reach 6-8”. They breed in the ponds, producing scores of tiny fish.

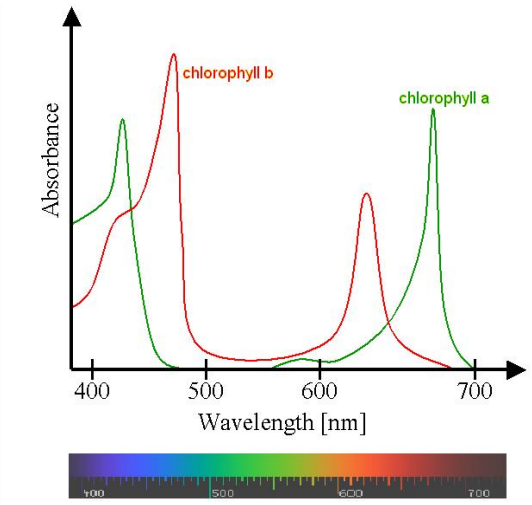
Science and Math of Gardening

Why are plants green?

Chlorophyll is the green pigment essential for photosynthesis, the process in which plants capture light and convert carbon dioxide and water into oxygen and glucose. It is because of photosynthesis that the earth has oxygen in its atmosphere.

There are two types of chlorophyll, A and B, which differ in the range of wavelengths that they absorb. *But neither type absorbs green light, so the plant reflects that light back, which is why they appear green*.





When plants are grown under artificial LED grow lights, it is generally more efficient to use lights that have only blue and red light, which makes them look purple.

(In color arithmetic,

white = red + green + blue

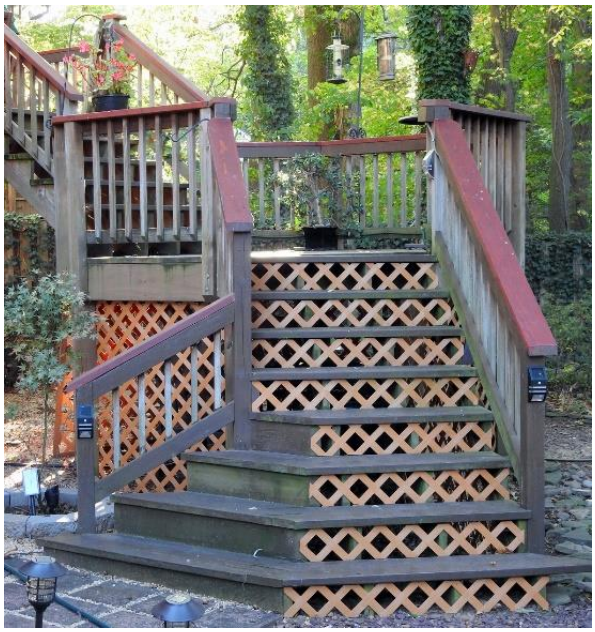
Thus white - green = red + blue = purple).

Mathematical patterns

Mathematical patterns are deeply embedded in the natural world. Even an informal woodland garden such as ours has many elements that reflect the underlying role of science and mathematics. For example, in our garden, you can find examples of simple geometrical shapes such as cones, spheres, circles and octagons.

This section of our deck is an *octagon* with a “sunburst” radial flooring design. The carpenter had to measure and make 72 carefully calibrated pieces for this to work. (8 sides x 9 pieces per side).

Repeated elements with regular spacing serve as contrast to the asymmetry of most of the garden.

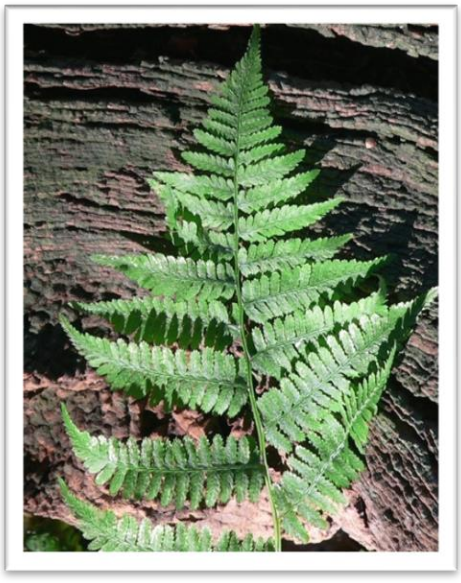


Counting rings

Occasionally one of our big trees dies or develops a disease and we must have it removed. It’s interesting to try to estimate the age of trees by counting the growth rings. This works well for trees in temperate climates like ours. The rings are formed due to the changes in growth speed through the seasons of the year, thus creating a visual record of the tree's age. Factors like climate, weather conditions, and the tree's health can affect the width of the rings. Based on ring counts, our big trees are about 150 years old, which means that they started life in about 1874, when **Ulysses S. Grant** was president! Importantly, the removal of those big trees changes the pattern of sun and shade in the garden, so we had to relocate some plants to other parts of the garden.

Fractals in the garden

Fractals are complex geometric shapes that are known for their intricate patterns and structures that appear similar at any scale. If you zoom in on a part of a fractal, you'll find it looks similar to the overall shape. Ferns are typical examples of plants that exhibit fractal patterns.



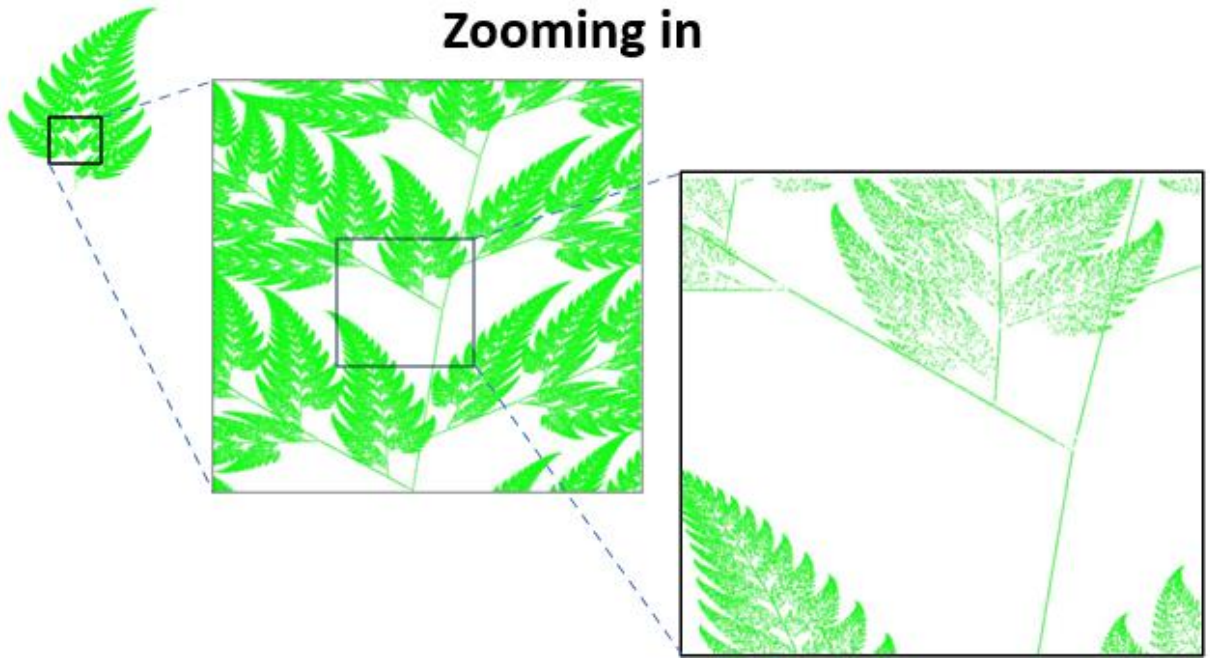
The Barnsley Fern: Looks like a fern, but it's actually math!

The structure of ferns has a surprising mathematical connection. A "Barnsley Fern", pictured here, is not a biological plant; rather it is a specific type of fractal graphic that *looks* very much like a natural fern. It's named after mathematician Michael Barnsley who first described it. This is a good example of how mathematical principles can model complex natural shapes. The structure shown here is generated completely by a surprisingly short computer algorithm.

The Barnsley fractal algorithm shown here creates a fern-like graphic with only 20-some lines of Matlab or Python code. Here's the code that generated that graphic. Creating a Barnsley Fern is a common task in computer programming and graphics design classes, when teaching abstract computer-science concepts such as recursion, coordinate transformations, and probabilistic algorithms.

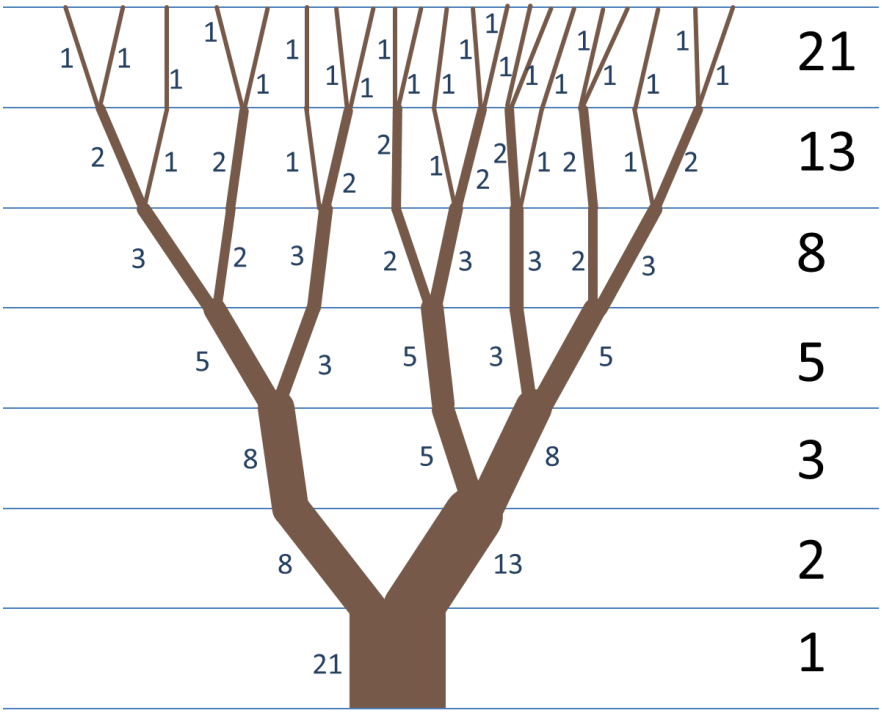
```
numPoints = 10000000;
x = zeros(numPoints, 1);
y = zeros(numPoints, 1);
for n = 2:numPoints
    r = rand;
    if r < 0.01
        x(n) = 0;
        y(n) = 0.16*y(n-1);
    elseif r < 0.86
        x(n) = 0.85*x(n-1) + 0.04*y(n-1);
        y(n) = -0.04*x(n-1) + 0.85*y(n-1) + 1.6;
    elseif r < 0.93
        x(n) = 0.2*x(n-1) - 0.26*y(n-1);
        y(n) = 0.23*x(n-1) + 0.22*y(n-1) + 1.6;
    else
        x(n) = -0.15*x(n-1) + 0.28*y(n-1);
        y(n) = 0.26*x(n-1) + 0.24*y(n-1) + 0.44;
    end
end
scatter(x, y, 1, 'g')
```

These three images show three different stages of zooming in to that computer-generated Barnsley fern graphic. As you zoom in, you can see that it is formed of millions of tiny individual dots (10 million in this example). (An ordinary computer can generate and plot the points at the rate of about 1 million per second). Of course, this is not the way that the plant actually grows; rather, it simply suggests some underlying similarity to the way that the gene expression and protein assembly work in developing ferns.



Fibonacci Numbers

The integer sequence in which each number is the sum of the two preceding ones is called a "Fibonacci" sequence. The name comes from *Leonardo Bonacci*, an Italian mathematician from the Republic of Pisa. The first mention of the sequence appears quite early, in 1202, where it was used to describe the growth of rabbit populations. Hundreds of years later, Leonardo Da Vinci noticed a connection to the growth of plants.

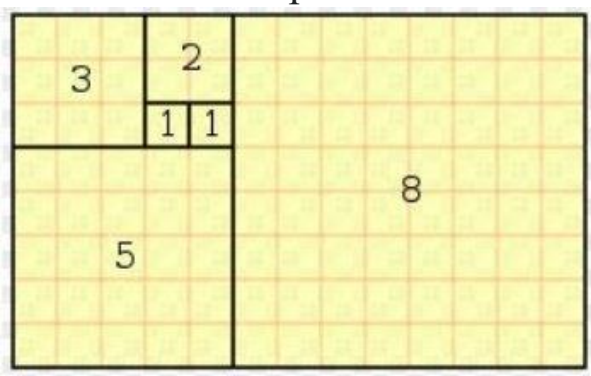


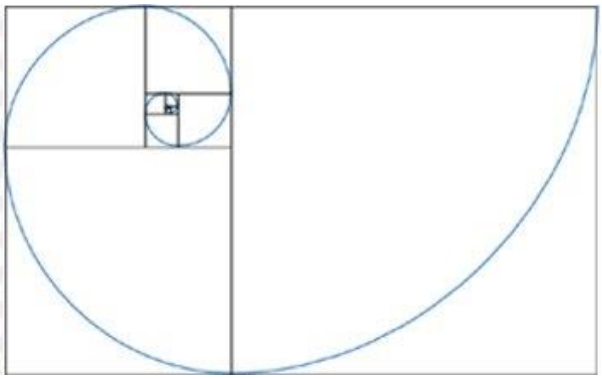
Leonardo Da Vinci wrote in his notebook that "…all the branches of a tree at every stage of its height when put together are equal in thickness to the trunk."

In other words, if a tree's branches were folded upward and squeezed together, the tree would look like one big trunk with the same thickness from top to bottom. In many trees, the branching pattern approximately follows a Fibonacci sequence. For example, a tree might produce one branch, then two, then three, then five, then eight and so on. Logically, the distribution of water and sap from the roots to the upper branches would require thicker branches below, so this arrangement is not surprising.

The Fibonacci Spiral.

If you divide a rectangle into squares whose sides are in a Fibonacci sequence, and then draw a line starting in the right bottom corner of the rectangle within the first square and then touch the outside corner of each succeeding square, you will create a kind of spiral called a Fibonacci *spiral*. You can spot instances of Fibonacci behavior by studying the way various plants grow. Many seed heads, pinecones, fruits, vegetables, and even some seashells, display spiral patterns that when counted express Fibonacci numbers.





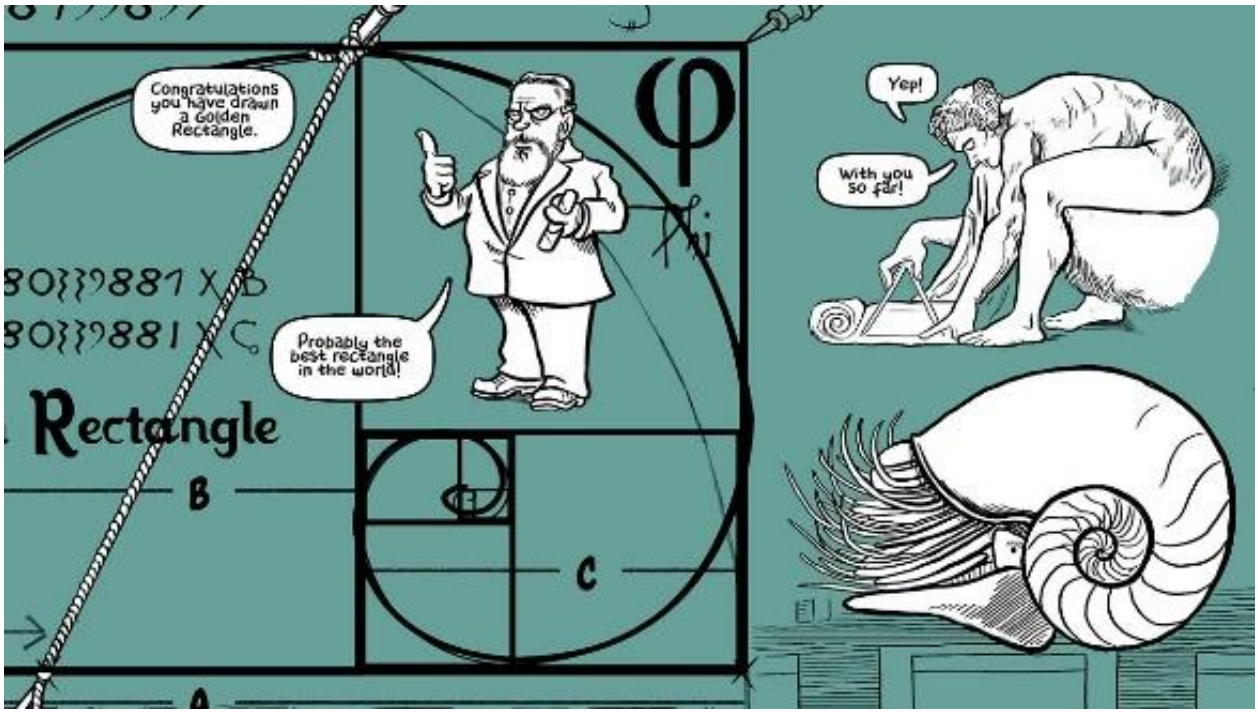
The Fibonacci spiral occurs surprisingly often in nature.

For example, you can spot instances of Fibonacci behavior by studying the way various plants grow. Many seed heads, pinecones, fruits and vegetables, snails, and some seashells, display spiral patterns that when counted express Fibonacci numbers.

The Golden Rectangle

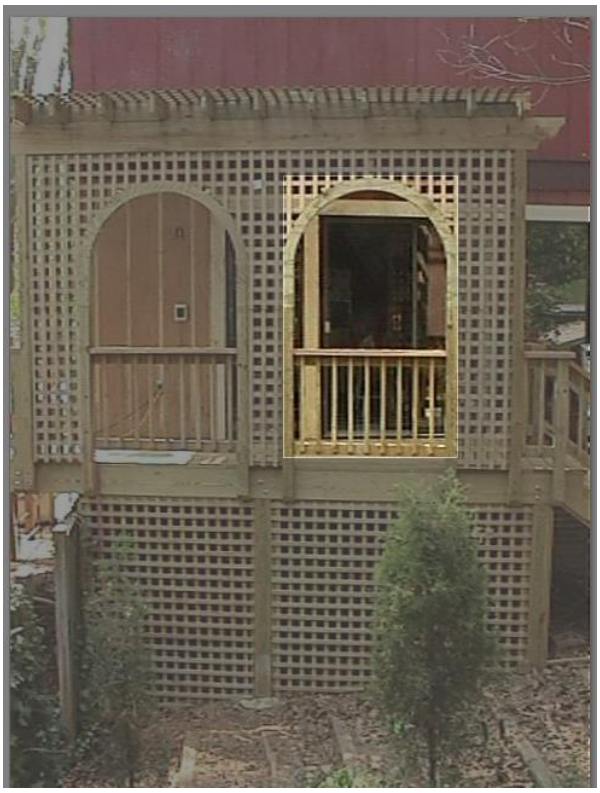
Science or 150-year-old scam?

The *Golden Rectangle* is a rectangle in which the ratio of its length to its width is 1.618, the so called the Golden Ratio. Many believe that this is one of the most visually pleasing of all geometric shapes. It shows up more than you might expect in architecture and graphic art. But could that just as easily be an example of "confirmation bias"? Confirmation bias is a cognitive bias that causes people to favor information that *confirms* their existing beliefs or hypotheses, while disregarding or minimizing evidence that *contradicts* them. It's a common and natural human tendency, but it can lead to flawed conclusions if not consciously checked. Probably, there are at least as many rectangles in architecture and graphic art that do *not* conform to the Golden ratio as those that *do*.



Even so, you can easily find examples. Here are two examples of structures in our garden that, apparently, do follow the golden rectangle rule. The brighter rectangular areas superimposed on these pictures are exactly Golden Rectangles. They do seem to match the proportions of the pictured items reasonably well.

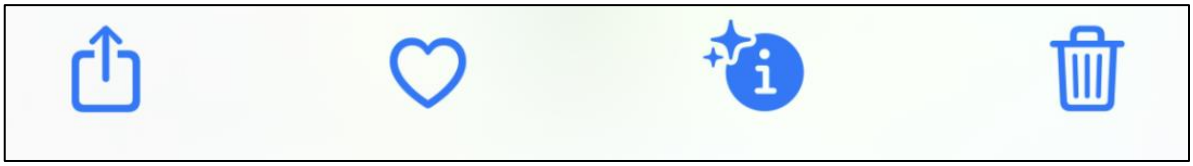
But when I made the Torii, I did not purposely build it with the Golden ratio in mind. And did the carpenter who built our arbor make those arches conform to that ratio? Maybe.

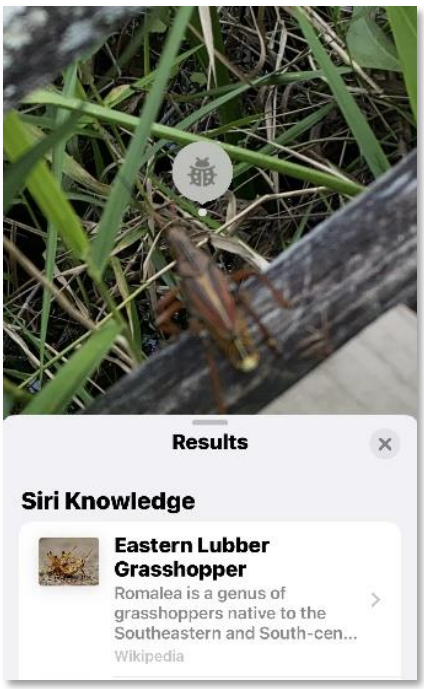


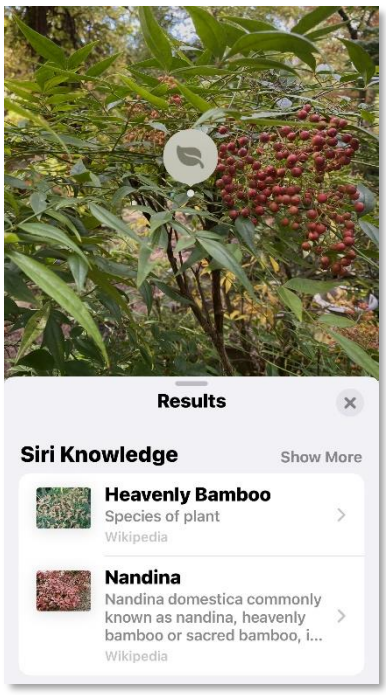
Here's another example, from a 1000-year-old Inca temple that we saw near Cusco, Peru. Did the Inca know about the Golden ratio? Or did I simply look through our photos of ancient temples until I found something that matched it pretty closely and ignore those that did not? You can decide for yourself by Googling "Golden ratio scam".

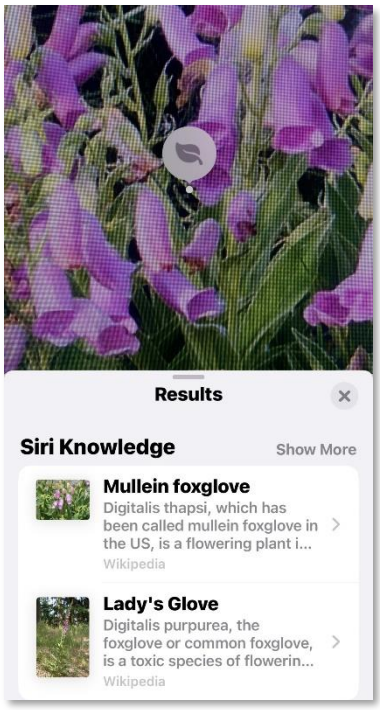
Artificial intelligence in gardening

Recent versions of the iPhone *pictures* app have an “identify” button that can identify items in a photo. For gardening purposes, it can be used to identify many plants and animals, including insects, such as the “Eastern Lubber” grasshopper shown in the screenshot on the left. The middle example identifies a plant and gives both the *common name* (e.g. Heavenly Bamboo) and the *botanical name* (Nandina). Note that for the foxglove in the right-hand screen shot, the fine print warns that this is a toxic plant. (The botanical name, “digitalis”, is also the name of a very powerful heart medication derived from that plant).





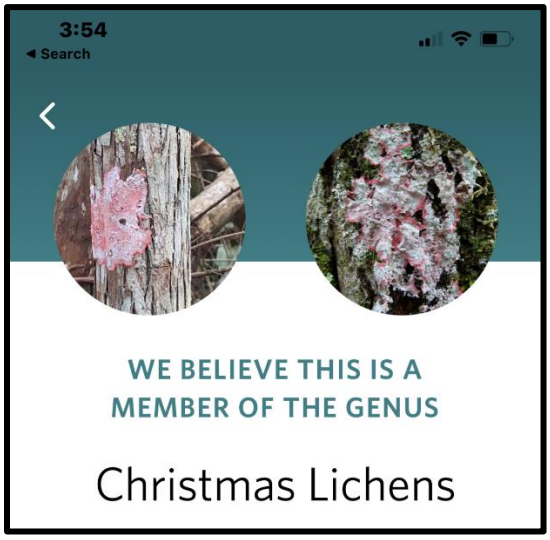


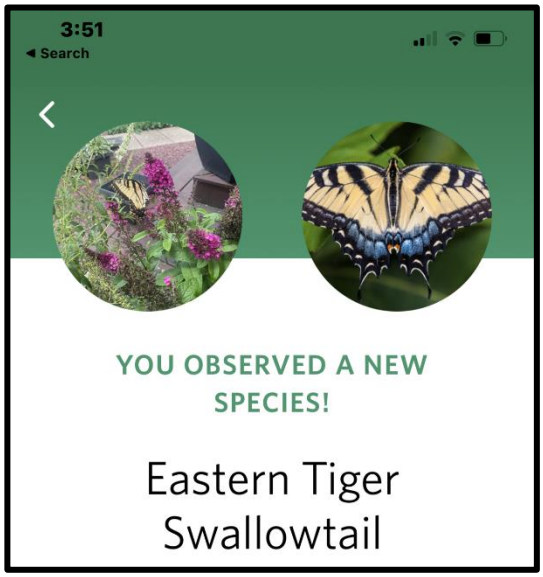


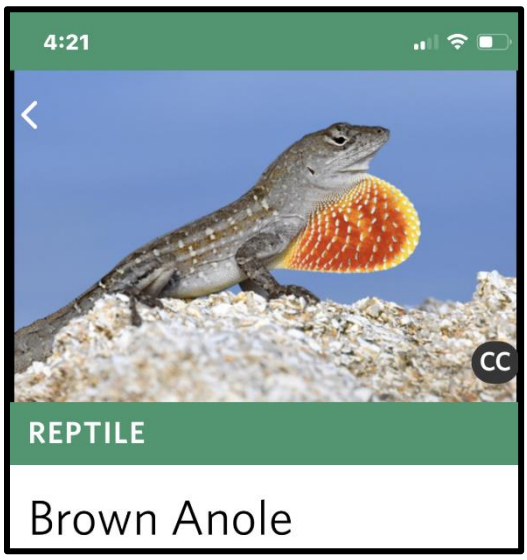
The Seek app

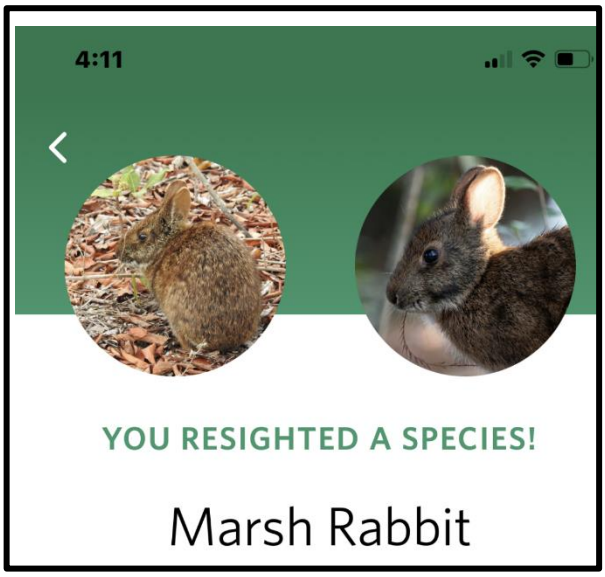
The free *Seek* app, by *iNaturalist,* is similar, except that you don't have to snap a photo – just point the camera at the item. These apps are handy for identifying unknown seedlings that can pop up in your garden or even for identifying one of your own plants whose name you have forgotten. In these examples it has identified the particular species of a lichen, a butterfly, a lizard, and a rabbit.

These apps are great for identifying unknown seedlings that can pop up in your garden or even for identifying one of your own plants whose name you have forgotten.





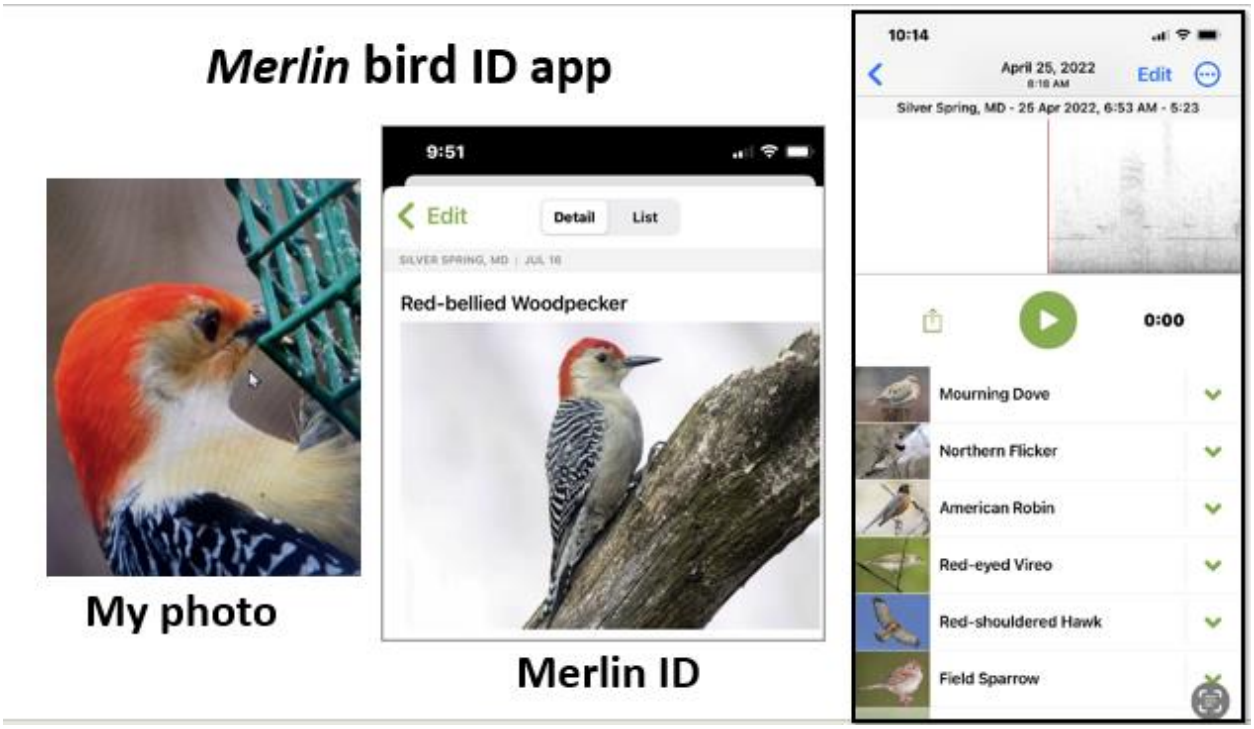




Identifying birds in the garden

We enjoy the songbirds that visit our garden and find The *Merlin* bird ID app, from the Cornell University ornithology program, is useful for identifying them. Just take a picture, or select that photo that you've previously taken, as shown here for this very colorful woodpecker which was visiting our suet feeder.

Merlyn can even identify birds from their *calls and songs*, which is especially useful since we typically *hear* more birds than we *see*. Each bird call it identifies is listed on the screen as it hears it, along with a picture.



Chatbots

Popular chatbots such as ChatGPT and Gemini can be a quick way to get specific answers to many garden questions. In recent versions, you can even upload or copy and paste photos or images and ask questions. For example, I uploaded this photo of one of our azaleas and asked the chatbot: "What is wrong with this azalea?"

ChatGPT replies: "The azalea leaf in the image shows a clear case of Exobasidium leaf gall, which is a common disease affecting azaleas….. Fungicide applications are generally not recommended for this disease as physical removal is usually effective, and the disease does not significantly harm the plant's overall health…."

Good to know.

Health effects of gardening as a pastime

- **Fresh air and bright light**
- **Moderate exercise**
- **Connection with living things**
- **Stress reduction.**
- **Dirt is good for your microbiome**

Gardening offers a range of health benefits, spanning physical, mental, and emotional well-being. These include moderate-intensity aerobic exercise and mental health benefits such as *stress reduction*. Gardening is a holistic activity that provides a sense of accomplishment and a connection to nature. It has been found to be beneficial in reducing the risk or slowing the progression of cognitive decline in older adults.

There is increasing evidence that exposure to plants and green space, and particularly to gardening, is beneficial to mental and physical health. "... exposure to plants and green space, and particularly to gardening, is beneficial to mental and physical health". (Richard Thompson, "Gardening for health: a regular dose of gardening", *Clinical Medicine* 18, 3, 2018). Research has suggested that people who grow up on farms, … have lower rates of Crohn's disease, asthma and allergies, likely because of their exposure to a diverse array of microbes. (Holly Burns, New York Times, April 17, 2024).

The author and physician Oliver Sacks wrote that "In forty years of medical practice, I have found only two types of non-pharmaceutical neurological 'therapy' to be vitally important: … *music* and *gardens*.

Audrey Hepburn once said that *"To plant a garden is to believe in tomorrow"*.
Personally, we find that gardening encourages patience and long-term thinking, giving us much to look forward to in the next growing season.

Conclusion

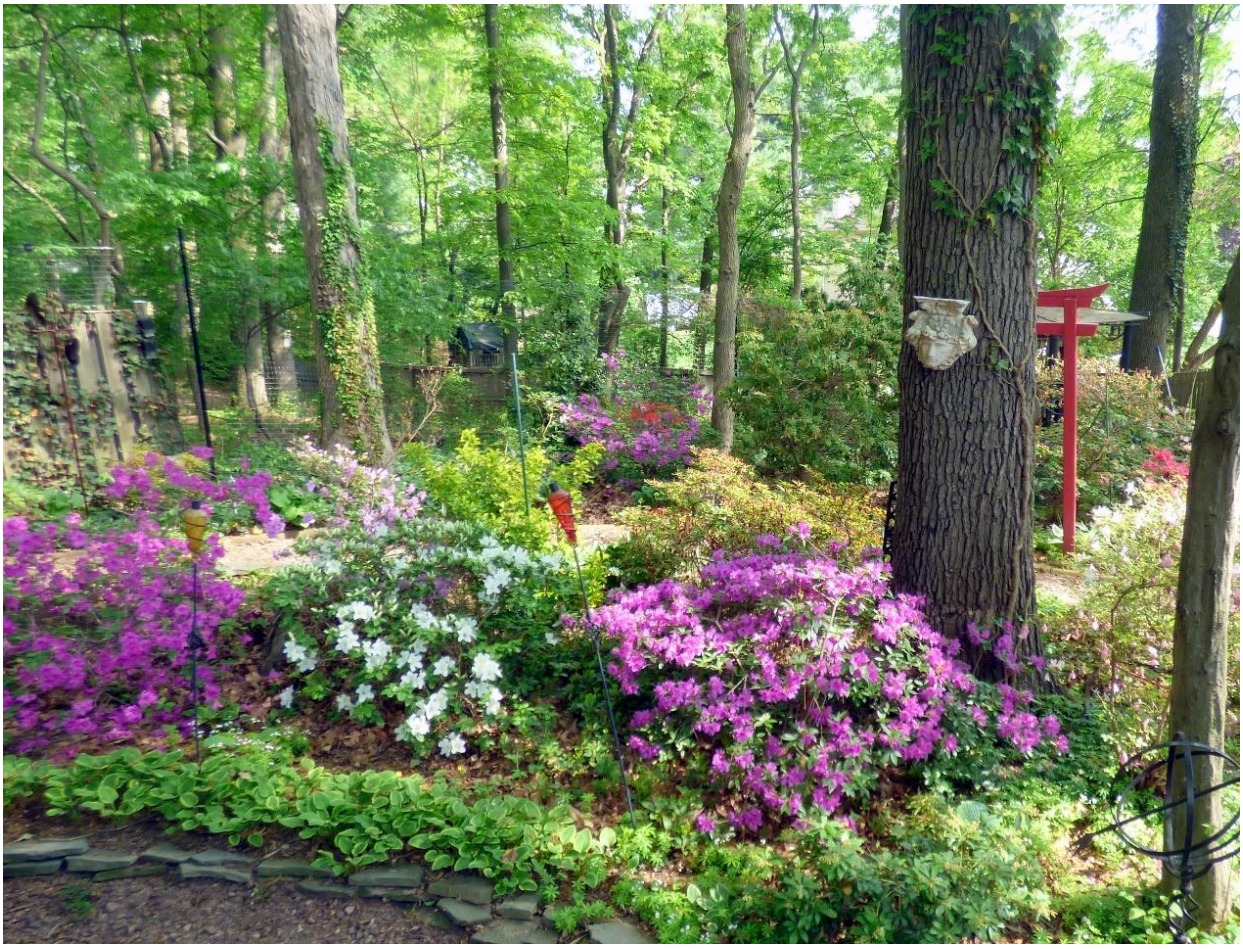
After 23 years, we still enjoy working on our garden, doing the day-to-day chores, strolling around, trimming overgrowth, or pulling a weed or two, buying new plants, dividing and transplanting old ones, giving away cuttings and plant divisions to neighbors and visitors, planning new projects, or just sitting and reading, often listening to music. Our garden is a *hobby*, not a *project*, so it will *never be finished*.

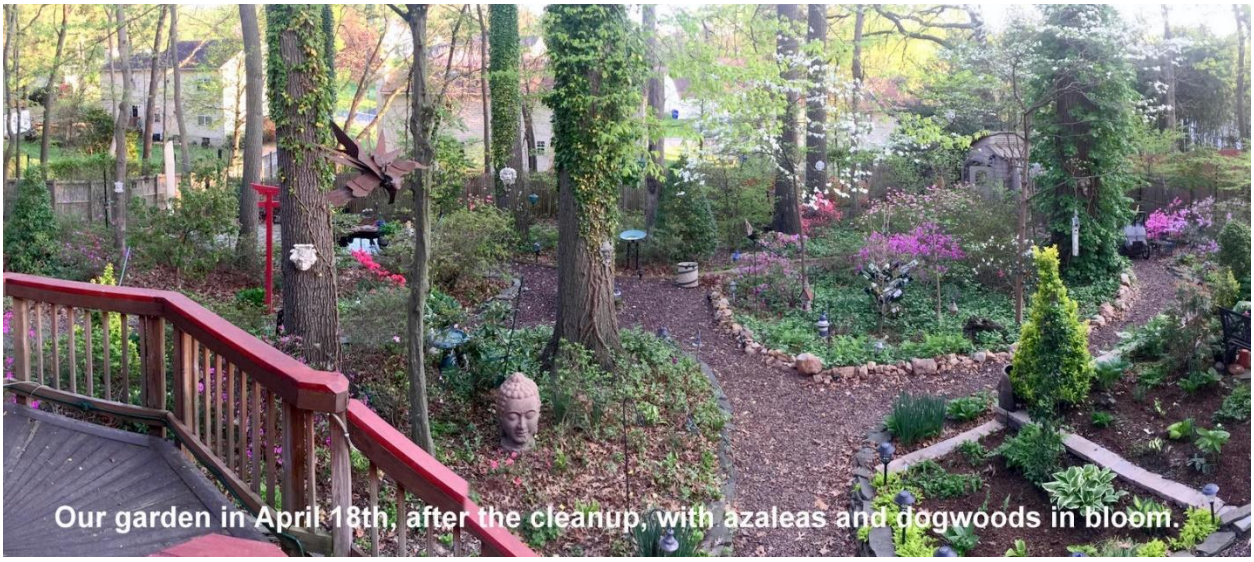
These two photos, taken 42 years apart, show that over that time, the trees have grown, the house has had a few upgrades, and a tranquil Asian-inspired garden has risen around it.

1981

2023

Addendum: Pictures of the garden's current state

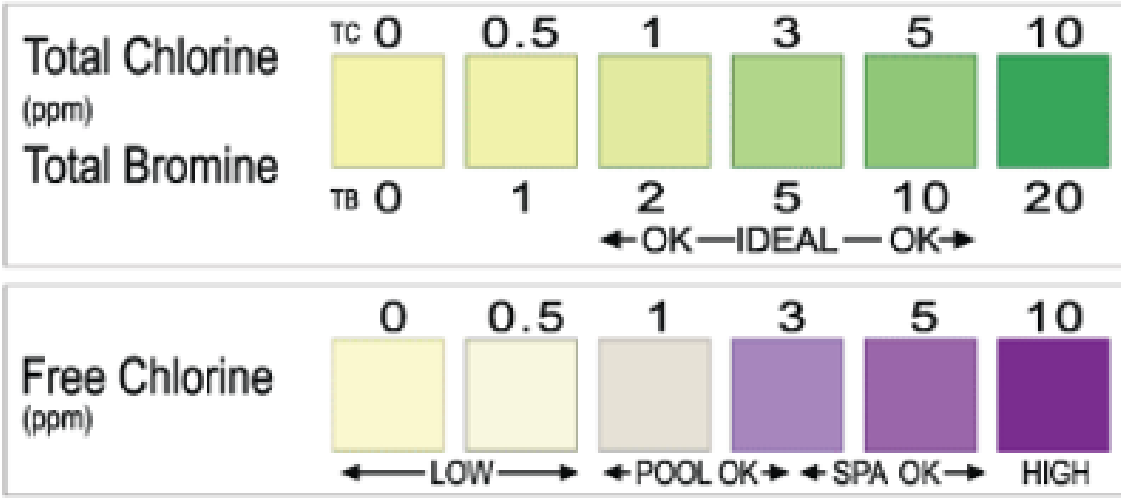




Our garden in April 18th, after the cleanup, with azaleas and dogwoods in bloom.

Addendum (only if a question is asked):

Why two chlorine measurements?



Two forms of chlorine are measured. The "**Total chlorine**" reading measures the concentration of chlorine in all chemical forms. The "**Free chlorine**" reading refers only to the concentration of *active* chlorine, before it reacts with anything. Why measure two forms of chlorine? Free chlorine is an active disinfectant, but when it is depleted, it doesn't just vanish; rather, it is mostly converted to *chloramines* by reacting with nitrogen-containing material from the bathers' perspiration, skin oils (and, yes, possibly urine). These chloramines have a strong smell, and they irritate the eyes, but they are weak disinfectants. Free chlorine, on the other hand, is a better disinfectant and it does *not* have that strong a smell. If the "Total chlorine" reading is significantly greater than the "Free chlorine" reading, it means that much of the disinfectant capacity has already been used up and it may be time to add more chlorine. More free chlorine is typically needed for spas (3-5 ppm) than for pools (1-3), because spas have less water per person than pools.