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Leaf It To Logo

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Logo LinX

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Leaf It to Logo

"Nature, to be commanded, must be obeyed."
—Francis Bacon, 1620

Many *Logo Exchange* readers can now look out their windows to see forests of red, orange, yellow, green and brown. Nature provides a timely opportunity in the fall to glimpse some of its mathematical and scientific wonders, hidden in the multi-colored carpet that showers and blankets the earth.

Discussions of photosynthesis can help students to understand why the leaves turn color. Leaf collections and trips to the woods can assist the identification and classification of tree species. Watercolor techniques can be used to capture the beauty on paper. Information can be gathered and shared about the many ways that people use wood. After school, trees can provide a high and friendly perch, a rough leaning post, even "home base" in a game of tag.

And, as you may have already guessed, trees and leaves can be commanded—in Logo, of course. In the process, some fascinating mathematical patterns emerge.

"....There's a leaf on the twig,
And a twig on the branch,
And a branch on the limb,
And a limb on the tree,
And a tree in the hole,
And a hole in the ground,
And the green grass grows all around, all around
And the green grass grows all around."

—as sung by Pete Seeger

Nature provides many branching structures for us to see, from the veins on a leaf to the limbs on a tree. But, as Bacon says, nature must be obeyed to be commanded. And, to be obeyed, Nature's patterns must be understood.

Vascular plants, such as lycopods, ferns, and trees, branch in basically two ways. Lycopods and some ferns branch dichotomously, as each new shoot subdivides or dichotomizes into two approximately equal apices. Each apice then grows for a time, and may dichotomize once again. The majority of vascular plants, though, branch laterally, in which the main shoot develops branches from buds in the leaf axils. Branch shoots then branch and rebranch in similar patterns.

A New Leaf

Leaves have vein configurations that also form branching structures, and leaf shapes accommodate venation. Veins are hollow tubules that transport starch made in the leaves to the stem, and down to the roots through phloem tubes. Veins also transport water, taken in by the roots, up to the leaves through xylem tubes.

There are three basic vein patterns in the leaves of deciduous trees: parallel, pinnate, and palmate. As an example of how mathematical patterns can be pinpointed in nature, then explored and generalized with Logo, let us examine leaf vein structures with the turtle.

Parallel venation, when drawn with the turtle, looks like this.

Parallel veins appear on flowering plants that are monocotyledons. A monocotyledon is a plant that has only one cotyledon, or seed leaf. The cotyledon may store food for the young plant before it can begin to produce true leaves, which take over food production.

Pinnate venation, when approximated with turtle graphics, looks like this.
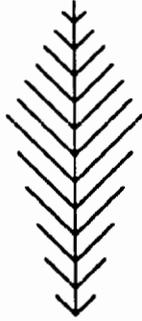
Veins, lobes (sections of leaves) and leaves themselves can be arranged in this pattern. The segments of a bird's feather also have a pinnate structure: opposite or alternate from one another along a common axis.

Palmate veins look something like this.
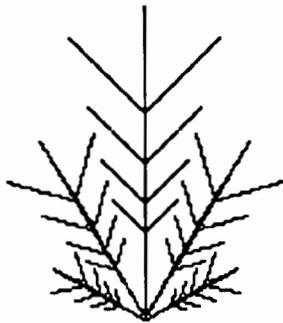
The structure refers to leaves, lobes, or veins radiating from a single point.

Be-leaf it or Not

Look closely at these diagrams. There is a pattern to the patterns. (And the pattern is mirrored in that statement!) The Encyclopedia Britannica defines "branching process" as:

> *"stochastic process in which an object can generate other objects, each of which can generate more objects, and so on."* (Micropaedia, 2:231)

Sound like recursion? Of course! Nature is infinitely recursive. Recursion, then, can be used to generate the vein patterns discussed above.

In this code, used to draw parallel vein patterns, a copy of the procedure is made in the computer's memory for each vein on the left half of the leaf.

```
TO PARALLEL :LENGTH :INCREMENT :LIMIT
IF :LENGTH > :LIMIT [STOP]
```

```
PU
BK 2
RT 90
FD 3
LT 90
PD
FD :LENGTH + :INCREMENT
BK :LENGTH + :INCREMENT
PARALLEL :LENGTH + 8 :INCREMENT + 2 :LIMIT
PU
FD 2
RT 90
FD 3 L
T 90
PD
FD :LENGTH + :INCREMENT
BK :LENGTH + :INCREMENT
END
```

The veins increase by 8 turtle steps plus an increment in length for each copy. Once the :LIMIT is exceeded, the multiple copies of the procedure are completed in reverse order of creation, with descending vein lengths. The recursive call marks the midpoint of the vein structure, or its line of symmetry.

(The inputs used for the sample leaf were: PARALLEL 5 3 75.)

This procedure makes multiple "v" shapes in increasing size,

```
TO PINNATE :LENGTH :LIMIT
IF :LENGTH > :LIMIT [STOP]
LT 45
FD :LENGTH
BK :LENGTH
RT 90
FD :LENGTH
BK :LENGTH
LT 45
FD 10
PINNATE :LENGTH + 5 :LIMIT
LT 45
FD :LENGTH - 5
BK :LENGTH - 5
RT 90
FD :LENGTH - 5
BK :LENGTH - 5
LT 45
FD 10
END
```

with a 10 turtle-step separation as the veins reach toward the tip of the leaf. Once the :LIMIT is exceeded, the other half of the leaf is completed. Unlike the PARALLEL vein pattern, where the line of symmetry is lateral (along the middle vein,) the line of symmetry for the PINNATE leaf is horizontal.

(The inputs used for the sample leaf were: PINNATE 10 35 .)

Finally, these commands make "vees" of increasing size, arranged from one radiating point. Note that this is the only tail-end recursive procedure in the set.

```
        TO PALMATE :LENGTH :LIMIT
        IF :LENGTH > :LIMIT [STOP]
        VEE :LENGTH :LIMIT
        BK :LENGTH
        LT 60
   VEE :LENGTH * 0.33 :LIMIT
   BK :LENGTH * 0.33
   RT 30
   VEE :LENGTH * 0.66 :LIMIT
   BK :LENGTH * 0.66
   RT 60
   VEE :LENGTH * 0.66 :LIMIT
   BK :LENGTH * 0.66
   RT 30
   VEE :LENGTH * 0.33 :LIMIT
   BK :LENGTH * 0.33
   LT 60
   PALMATE :LENGTH * 1.33 :LIMIT
   END


   TO VEE :LENGTH :LIMIT
   FD :LENGTH
   BK :LENGTH / 3
   LT 45
   FD :LENGTH / 3
   BK :LENGTH / 3
   RT 90
   FD :LENGTH / 3
   BK :LENGTH / 3
   LT 45
   FD :LENGTH / 3
   END
```

(The inputs used for the sample leaf were: PALMATE 50 150.)

Goethe's Guidelines

> *"Nature goes her own way, and all that to us
> seems an exception is really according to order."*

—Goethe (1824)

I'll never forget the day when an excited 6-year-old came running to me during recess, eyes bright, with a beautiful red leaf in her hand. She held it up for me to see, using a nearby tree as the backdrop.
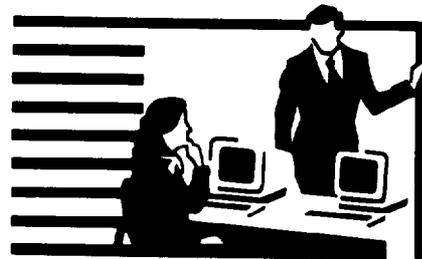
"See?" she exclaimed. "The branches on the leaf are like the ones on the tree."

I have her to thank for revealing a recursive series of mysterious natural patterns, that extend from the leaves, to the branches, to the roots of a powerful idea.

Judi Harris was an elementary school computer use facilitator, graduate education instructor, and computer consultant for a number of public and private schools in Pennsylvania. She is now a doctoral student in education at the University of Virginia. Her CompuServe number is 75116,1207. ▲