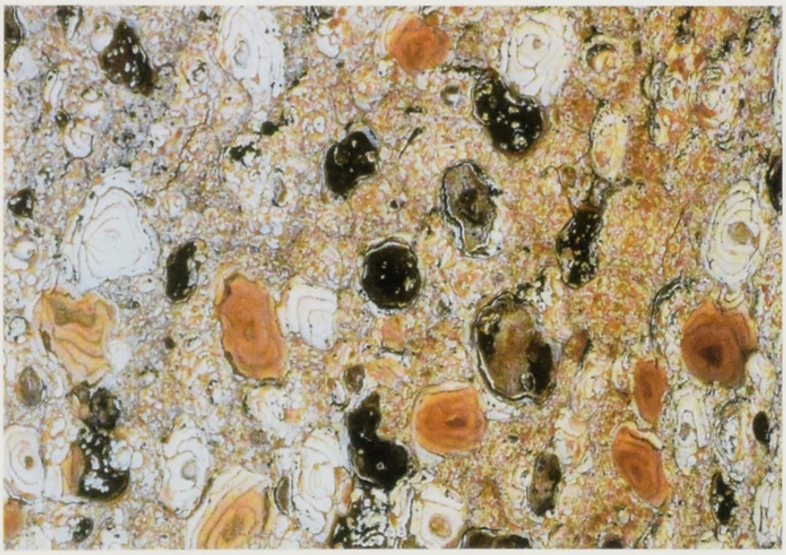

In the fading light of dusk, satiny bark curls on a greenleaf manzanita (*Arctostaphylos patula*) take on a purplish sheen.


The bark of whitebark pine (*Pinus albicaulis*) is much finer-textured than that of most pines and resembles an extreme close-up of an impressionist painting.


The trunks of giant sequoias (*Sequoiadendron giganteum*) are protected by thick layers of fibrous, fire-resistant bark.

Bark: From Abstract Art to Aspirin

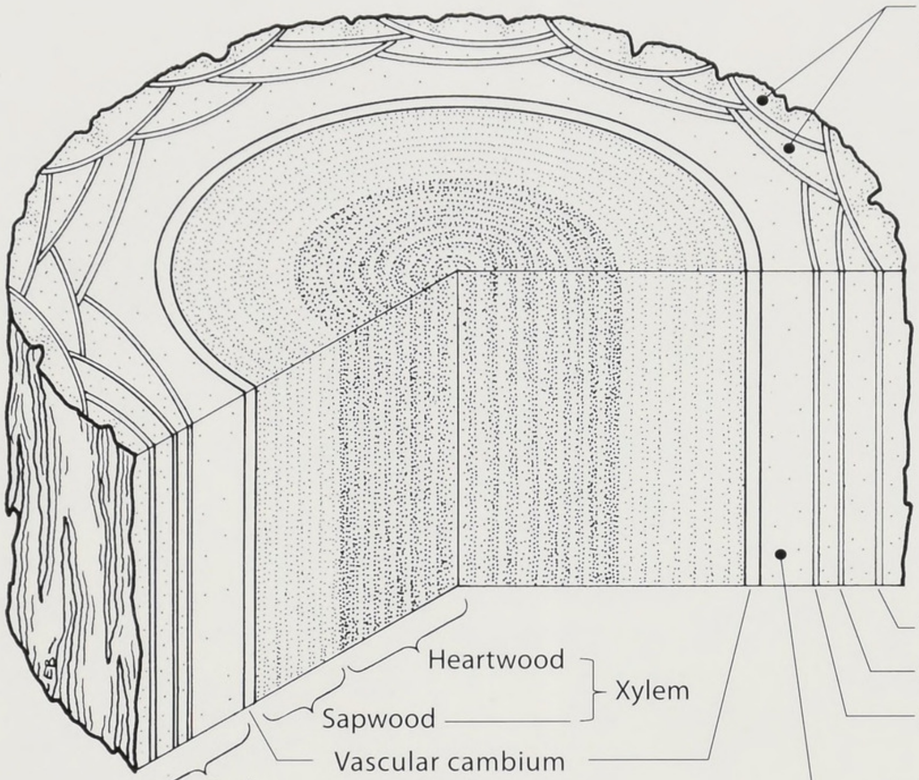
Eva Begley

To many people, bark is just the gray or brown stuff that covers tree trunks, but it's actually much more interesting than that. Woody dicotyledons and gymnosperms depend on their bark to keep insects and pathogens out. Bark also minimizes evaporation of water from trunks and branches. The fire-resistant bark of giant sequoia (*Sequoiadendron giganteum*) grows up to 18 inches [45.7 centimeters] thick and has allowed some individuals to thrive for more than 3,000 years. Cork oak (*Quercus suber*), native to southwestern Europe and northwestern Africa, can also survive forest fires thanks to its thick bark.

While functional for the tree, bark can be aesthetically pleasing for us. The bark of some trees shows surprising colors, including green, blue, and orange. It can be rough or smooth, stringy or flaky; it can peel away in long shreds or curl like chocolate shavings on an elaborate gateau. The textures and patterns in bark may remind you of abstract painting or sculpture, jigsaw puzzle pieces, or an old cable-knit sweater. Bark's charms are sometimes accentuated when festooned with lichens or providing a foothold for epiphytes.

Anatomy of a Tree

As a tree grows taller and adds more leaves and branches, its weight increases. To support the added weight, the trunk and branches grow in diameter. They do that thanks to a sleeve of almost-forever-young cells called the vascular cambium. During the growing season, these cells divide many times, mainly in a plane parallel to the surface of the trunk or branch. Cells produced on the inner side of the vascular cambium become xylem, which, as so-called sapwood, conducts water and minerals absorbed by the roots to the rest of the tree, then turns into the strong woody core of the tree—the heartwood, which is usually darker in color



What Is Bark?

Botanists usually use the term "bark" to refer to everything outside the vascular cambium: phloem; phloem fibers; the innermost, live cork cambium and all its inner and outer derivatives; and older, dead cork cambia along with whatever else has accumulated outside the live cork cambium. The cork cambium and its products (that is, phellem and phelloderm) are collectively referred to as "periderm." The live, deeper-seated components of the bark are sometimes called "inner bark."

than the sapwood. Cells produced on the outer side of the vascular cambium become phloem, which conducts sugars and other carbon-based nutrients throughout the tree. In temperate climates, the xylem and phloem formed early in each growing season usually contain lots of relatively large cells; cells formed later in the growing season are smaller. As a result, the xylem and phloem are built up of concentric rings, each ring constituting one year's growth. Phloem rarely lasts more than a few years (more on that in a moment). Xylem, however, can last well beyond the life of the tree in the form of standing snags or downed wood, or as lumber in buildings and furniture. Similar processes take place in roots.

Once in a while, to keep up with the increasing girth of the tree, the cells of the vascular cambium divide in a radial plane. The phloem and most other cells outside the vascular cambium, though, have matured and aren't able to keep dividing or enlarging—they get stretched to the breaking point. That triggers the development of a new layer of squat, dividing cells, the cork cambium or phellogen, usually near the stem's surface. Like the cells of the vascular cambium, those of the cork cambium divide mainly in a plane parallel to the surface. (Interestingly, the cork cambium isn't necessarily active at the same time as the vascular cambium—the cork cambium seems to function more on an as-needed basis, perhaps in response

Front and side views of the bark of sugar pine (*Pinus lambertiana*). The crevices are deep enough to peer into and see the longitudinal arrangement of the bark plates formed by successive cork cambia.

to the damage caused by stretching and rupturing of cells around the perimeter of the trunk or branch.) The relatively few new cells formed on the *inner* side of the cork cambium, collectively called the phelloderm, usually stay fairly unspecialized; they may separate a bit, allowing some air circulation between them, and in some species they become photosynthetic, coloring the bark green. Far more new cells are produced on the *outer* side of the cork cambium; but except in a few aquatic or wetland plants, they stay tightly packed, with no air spaces between them. Unlike animal cells, each plant cell is enclosed by a wall composed primarily of cellulose. As the cell matures, its wall may be reinforced by additional layers of cellulose, or, in most cells in the xylem, by a strong, rigid substance called lignin. In the outer derivatives of the cork cambium, the cellulosic wall is lined by layers of a waterproof substance, suberin, sometimes alternating with sheets of waxes or lignin. Eventually, these outer derivatives die and their interiors become tiny gas-filled pockets, giving them a squishy feel: they have become phellem, commonly called cork.

Of course that isn't the end of the story, because in the meantime the vascular cambium continues increasing the plant's girth. Eventually, that first layer of cork also gets stretched excessively and starts to crack. In cork oak, occasional cell divisions in a radial plane allow the cork cambium to keep pace with the growth in girth, but more commonly the first-formed cork cambium dies and new cork cambium forms deeper in the trunk or branch, sometimes even in the outer, older part of the phloem. In some species, each new cork cambium forms a complete sleeve; other species produce many small, overlapping patches of cork cambium, a bit like curling shingles on an old roof. Often, these later cork cambia are initiated right underneath cracks in the tree's surface, like internal bandages, ensuring that no crack gets deep enough to damage the living interior of the tree. This process is repeated over and over throughout the life of the plant. Eventually, a complex structure is formed, with everything outside the innermost, most recently formed cork cambium either dead or dying.

Bark Variations

The texture of the bark depends largely on the shape and location of successive cork cambia and on the types of cells "trapped" between them. Chinese or lacebark elm (*Ulmus parvifolia*), for example, has many overlapping, irregularly shaped cork cambia fairly close to the surface. Trees with deeper-seated cork cambia have rougher, craggier bark, like northern red oak (*Quercus rubra*) and tulip tree (*Liriodendron tulipifera*). Layers of thin-walled cells, whether the inner derivatives of the cork cambium or part of the phloem, are structurally weak, so bark characterized by such layers is likely to flake or peel off easily. Phloem sometimes contains lots of long, skinny, thick-walled but pliable cells, called fibers; as old phloem gets incorporated into the bark, these fibers give it a stringy texture. In some pines, the outer derivatives of the cork cambium consist of alternating bands of suberized cork cells

The bark of lacebark elm (*Ulmus parvifolia*) has a jigsaw-puzzle-like pattern.

This Garry oak, also known as Oregon white oak (*Quercus garrayana*), has deeply creviced bark.

The bright green bark of palo verde (*Cercidium floridum*), a member of the legume family (Fabaceae), can be quite variably patterned; this particular tree shows kite-like shapes.

River birch (*Betula nigra*) is admired for its multicolored, dramatically peeling bark. Close examination reveals that each papery sheet is covered with the long transverse lenticels often found in the genus.

and short, heavily lignified cells, called stone cells, that harden the bark.

Layers of dead, waterproof cells are fine for protecting trees from bugs, desiccation, and other dangers, but they also hinder gas exchange. Like most living things, the live cells inside trunks and branches, including those of the vascular cambium and phloem, need oxygen. Lenticels provide the solution. They are small patches of loosely packed cells with lots of air spaces between them that the cork cambium produces here and there instead of dense arrays of cork cells. In some species, the lenticels are hidden at the bottom of cracks in the bark; in others, such as paper birch (*Betula papyrifera*), they form a prominent and characteristic part of the bark's appearance. Gases diffuse in and out through the lenticel's air spaces, allowing the live interior parts of the trunk to "breathe." Also, any green, chlorophyll-containing cells in the bark produce oxygen as a byproduct of photosynthesis. That oxygen gets snapped up by nearby, live, non-photosynthetic cells, which give off carbon dioxide, which their photosynthetic neighbors then use to produce more sugars—as neat a solution as any recycling system devised by engineers.

Different species of the same genus can have very different bark colors and patterns. Take the birches, for example. Sweet birch (*B. lenta*) has rather ordinary-looking gray bark, but paper birch and European white birch (*Betula pendula*) have smooth white bark with long, transverse lenticels. The lenticels of western water birch (*B. occidentalis*) form a similar pattern against a beautifully shiny, pinkish brown background, while in yellow birch (*B. alleghaniensis*) the background is yellowish brown or dark gray. River birch (*B. nigra*) is often grown for the tan, reddish brown, and dark gray sheets of bark that peel off its trunk in shaggy disarray. The maples are even more varied. Many have bark that is plain gray in color, albeit with various textures. But then there's the aptly named paperbark maple (*Acer griseum*) with peeling sheets of cinnamon colored bark, Father David's maple (*A. davidii*) with its characteristic vertical white squiggles on a bright green background, and coral bark maple (*A. palmatum* 'Sango-kaku'), a Japanese maple that adds color to winter gardens with its brilliant red branches.

Bark's appearance often changes with age, and it's common for the bark of twigs and young branches to differ from that of older limbs. An extreme example is European white birch, in which the rough, gray to almost black bark near the base of the trunk forms a stark contrast to the creamy white bark higher up. And in aspen (*Populus tremuloides*), wherever the trunk has been wounded, be it by fungal attack, natural abscission of the lower branches as the tree gets taller, a bear climbing the tree, or lonely sheepherders or bored teenagers carving their names into the tree, the bark becomes black and fissured, very different from the tree's normally smooth, pale bark.

Bark Beneficiaries

Thick bark has some obvious benefits to trees, but the cracks and fissures in that bark can also provide good habitat for other species. Especially on rough-barked trees, enough soil, organic debris, and moisture can collect to fill minute pockets in which lichens, mosses, and larger epiphytes such as ferns and orchids can get a toehold. Often, different species of lichens and mosses grow on the upper and lower surfaces of leaning tree trunks and large limbs.

NANCY ROSE

Younger branches of coral bark maple (*Acer palmatum* 'Sango-kaku') are bright red.

Black bears have left permanent calling cards on the trunks of this quaking aspens (*Populus tremuloides*).

The bark on the upper part of these old red fir (*Abies magnifica*) trunks is almost hidden by wolf lichen (*Letharia* spp.); the lichens don't grow below the average snow line in the grove.

Some mosses and lichens may prefer certain species of trees; for example, in the northern Sierra Nevada mountains, wolf lichen (*Letharia* spp.) usually seems to grow more luxuriantly on the trunks of red fir (*Abies magnifica*) and incense cedar (*Calocedrus decurrens*) than on the trunks of nearby seemingly equally rough-barked pines, though, the pines' *branches* sometimes bear dense chartreuse masses of this lichen.

Insects use the cracks and fissures in bark as places to hide; some feed on bark; others lay their eggs on or under the bark of dead or dying trees or trees stressed by drought. Collectively, these insects and their larvae provide a smorgasbord for insectivorous birds such as nuthatches, creepers, and woodpeckers. Sapsuckers (*Sphyrapicus* spp.), also members of the woodpecker family, drill horizontal rows of holes into the trunks of favorite tree species to feed on the nutritious inner bark and the sap that oozes out, along with insects caught in the flow. Subsequently, other woodpeckers, orioles, hummingbirds, warblers, and even some insects and mammals feed at these "sapsucker wells."

Nuthatches (*Sitta* spp.), gray jays (*Perisoreus canadensis*), and some species of woodpeckers cache nuts, seeds, and even dead insects by thrusting them into bark crevices, but acorn woodpeckers (*Melanerpes formicivorus*), native to the western United States and parts of Mexico, have raised the art of food storage to a new level. These social birds typically live in families of two to a dozen or more animals, and each family creates a communal acorn larder in the bark of thick-barked living trees, the bark or wood of standing snags, and even utility poles and fence posts. Acorns are stored in individual cubbyholes, each of which takes a total of about an hour to make although it's rarely finished in one sitting; typically, family members take turns drilling it over a period of a few days. A "granary tree" may have anywhere

Sapsuckers drilled multiple rows of holes in this white alder (*Alnus rhombifolia*). Extensive sapsucker drilling may partially girdle trees, which can eventually lead to the tree's decline.

Acorn woodpeckers constructed a granary in this valley oak (*Quercus lobata*). The tree is now dead, but the presence of a few remaining slabs of bark full of the distinctive holes indicates that the birds started their work while the tree was still alive or at least still had bark on it.

from one or two thousand to tens of thousands of acorn-sized cubbies, and each year the birds drill many more holes to replace those lost as limbs break off and old trees fall. In fall, the birds harvest ripe acorns from the branches of nearby oak trees (they rarely collect acorns that have already fallen to the ground), pry off the caps, and hammer the acorns into the predrilled holes. The flat end of the acorn, which provides a better surface for hammering, is almost always on the outside. If the first hole is too large or too small, the bird will try other holes until it finds one that is just the right size for a snug fit. The acorns provide an important food source for the family throughout the winter and early spring. Contrary to earlier belief, it seems that the birds feed directly on the acorns, not just on the insect larvae that sometimes infest them.

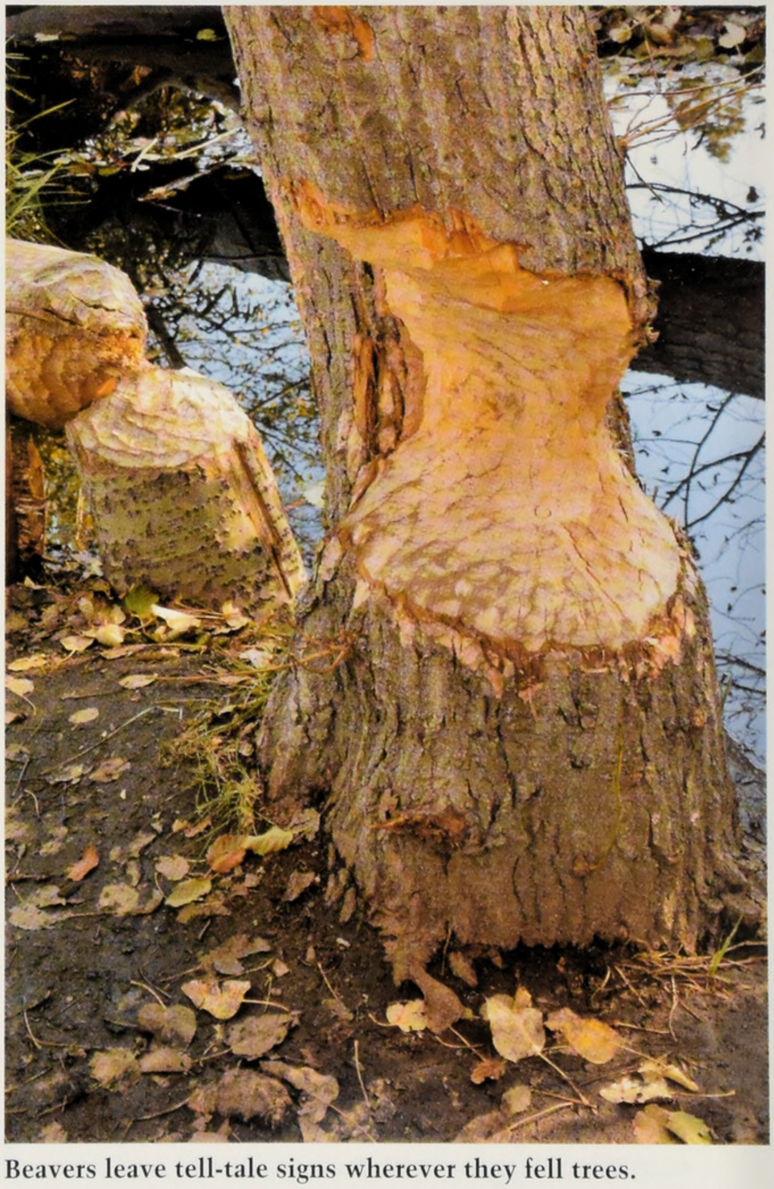
Some mammals feed directly on bark. Porcupines and snowshoe hares like conifer bark. Moose will eat bark in winter if nothing more to their liking is available. Beavers, on the other hand, love bark, especially aspen (which is abominably bitter to human taste buds), but also other *Populus* species, willows (*Salix* spp.), birch, red-osier dogwood (*Cornus sericea*), and other species. I've even seen conifers (specifically, lodgepole pine, *Pinus contorta* subsp. *murrayana*) felled by beavers. During the growing season, the animals eat the buds, leaves, and twigs of these plants as well as the bark. In winter, bark is their primary food. Since beavers can't climb trees to reach the goodies up in the canopy, their solution is to gnaw down the entire tree. They are amazingly efficient at this: I once watched a beaver scramble out of an Ozark river and up a steep bank to a young

Acorn woodpeckers drilled holes for various acorn sizes in this blue oak (*Quercus douglasii*).

maple, with a trunk diameter of maybe 4 to 5 inches (10 to 13 centimeters). Within moments the tree's crown was swaying wildly, and in less than five minutes the beaver had dragged the entire tree through thick undergrowth back into the water and was swimming away with it. The animals don't waste much: debarked trunks and branches are used to construct or reinforce the beavers' lodges and the dams that they are famous (or notorious, depending on your point of view) for building. And wherever winters are typically cold enough for ponds to freeze over, beaver families cache enough young branches each fall to last them through the winter, usually by jamming the butt ends deep into the mud at the bottom of the pond, sometimes by building floating rafts, placing already peeled logs and less-preferred foods such as alder on top of the raft and favorites like aspen and willow below so that the branches are easily accessible from underwater.

Canoes, Quinine, and Corks

Bark benefits people too. Leafing through Daniel Moerman's encyclopedic *Native American Ethnobotany,* I get the impression that Native Americans found the bark of just about every native tree species useful in some way, be it medicinally or to make baskets and other containers, rope, cloth, dyes, and many more items. In winter, the Lakota, Blackfoot, and Cheyenne fed their horses with cottonwood and aspen bark. Some tribes used slabs of bark as roofing material. In the upper Midwest the Ojibwe (also known as the Chippewa) stitched sheets of paper birch bark together with spruce roots



Beavers leave tell-tale signs wherever they fell trees.

The bark of cork oak (*Quercus suber*) is carefully hand-harvested. The bark regrows and can be harvested again in about ten years.

to waterproof their homes. In fact, so versatile is the bark of paper birch that it was used for everything from canoes to kitchen funnels; as Moerman puts it, "Nearly any kitchen utensil common to the white man could be duplicated in birch bark by the Ojibwe."

The homes and barns of North America's European settlers were often roofed with the bark of American chestnut (*Castanea dentata*). Some of those buildings might have been painted using brushes made by boiling basswood (*Tilia americana*) bark in lye, then pounding it to extract its hemp-like fibers, a technique the settlers learned from Native Americans who made rope, sewing thread, and woven bags from basswood bark. The settlers probably wore shoes made of leather processed with tannins extracted from hemlock or oak bark, and some of their clothes may have been dyed with quercitron, derived from the yellow-orange inner bark of the black oak (*Quercus velutina*). Alone or in combination with mordants or other dyes, quercitron can yield colors ranging from bright yellow to warm browns. It was used commercially until well into the twentieth century, when cheaper synthetic dyes were discovered.

Human health has also benefitted from certain chemical compounds in bark. To limit being incessantly munched by herbivores and damaged by insects, some plants produce chemical defenses. Some of these defenses are simply metabolic by-products, such as the calcium oxalate crystals that render the bark of some pines unpalatable to browsers. Others, such as various alkaloids, tannins, and cyanogens (which give cherry bark its distinctive bitter almond scent and cough-suppressing properties), require greater metabolic input and their synthesis consumes nutrients, but they provide valuable protection to long-lived plants. It's these same compounds that make the bark of some species medically useful.

Two of the most famous drugs we owe to bark are aspirin and quinine. The Greeks used willow bark extracts as long as 2,400 years ago to relieve pain; similarly, many Native American tribes used willow bark to treat colds, fevers, and headaches. In 1827, a French chemist, Henri Leroux, isolated a compound he called salicin from willow bark; a related compound, salicylic acid, was discovered in 1839. Both compounds, though, cause nausea and gastric pain, and chemists continued searching for an effective pain reliever. Another related compound, acetylsalicylic acid, was discovered in 1853, but it wasn't until 1899 that its pharmaceutical value was recognized and the Bayer Company began marketing it as aspirin.

Like many of the 60 or so species of manzanita (*Arctostaphylos*), this one (species unknown) displays eye-catching bark.

Quinine and other antimalarial alkaloids are derived from the bark of several species of *Cinchona,* native to the Andes and related to coffee. There are conflicting accounts of how *Cinchona* trees reached the Old World. In the nineteenth century, both the English and the Dutch tried to smuggle seeds or seedlings out of South America, where the quinine trade was tightly controlled. Eventually the Dutch established large *Cinchona* plantations on Java, and through breeding and selection increased the bark's alkaloid yield from 7% to 17%. Today other drugs are available, but the microscopic protozoan that causes the disease is becoming resistant to many of them, and millions of people are still affected by malaria annually.

To conclude on a happier note, though, where would we be today without the cork oak, whose thick outer bark is used to make flooring, fishing rod handles, woodwind instrument joints, and wine bottle corks by the billion? People have used cork at least since Roman times: Pliny the Elder, writing in the first century A.D., listed fishing floats, women's winter shoes, and stoppers for wine jars among its uses. It takes a cork oak tree 25 to 40 years to build up a layer of cork thick enough to harvest, but the first harvest consists of hard, crumbly material good only for bulletin boards and insulation. If the cork is removed carefully, a new phellogen develops in the phloem 25 to 35 days later. The tree resumes cork production and can be harvested again 9 or 10 years later. Not until the third harvest, however, is the cork of sufficient quality for wine stoppers. The trees typically live 250 to 350 years, so each tree can be harvested many times. The practice of harvesting bark in cork oak forests actually helps preserve this unique ecosystem from land development so many conservation organizations promote the use of natural cork. And even though oenological research suggests that it doesn't really make much difference whether wine is sealed with natural cork, synthetic stoppers, or screw caps, yanking a plastic stopper out of a bottle just doesn't provide the same sort of tactile pleasure that pulling a real cork does. So pull a real cork, pour a glass, and drink a toast to bark.

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