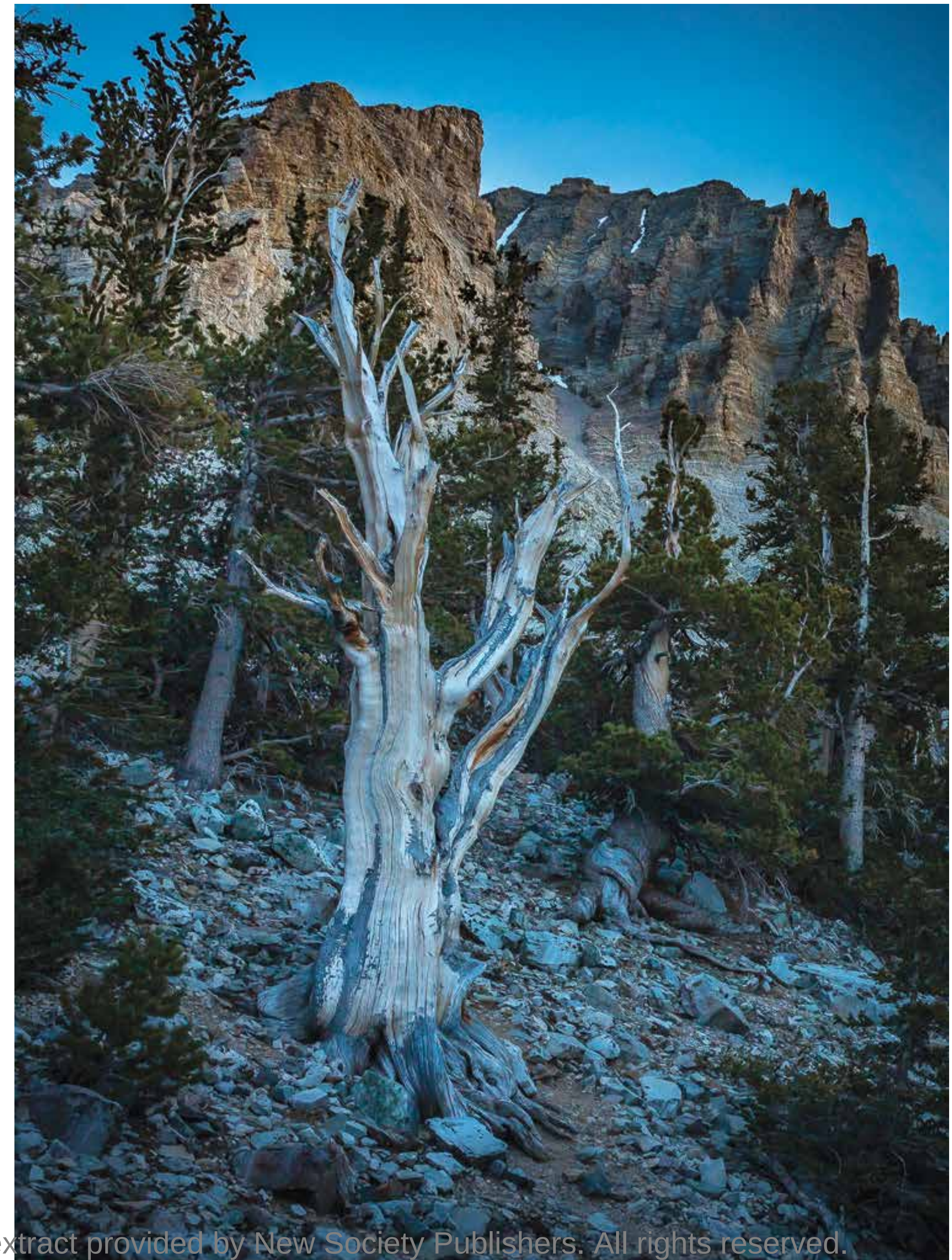
Introduction

Author John J. Albers in his garden.

Gardening has been my passion for more than three decades. I enjoy planting, watching the plants grow, and monitoring the changing plant communities through the seasons and years. Over the past 20 years, I have created and maintained a four-acre garden in Bremerton, Washington. I joyfully open this botanical oasis to the public for tours and for workshops on a variety of horticulture topics. Not only is Albers Marcovina Vista Gardens (www.albersvistagardens.org) a sanctuary for plants, wildlife, and visitors, it is also a laboratory in which I experiment with sustainable gardening best practices on a constantly expanding collection of plants. From this labor of love, I developed my first book, *Gardening for Sustainability: Albers Vista Gardens of Kitsap* (Vista Gardens Press, 2013), and my second book, *The Northwest Garden Manifesto: Create, Restore, and Maintain a Sustainable Yard* (Mountaineers Books, 2018).

Albers Vista Gardens showcases many kinds of plants, including 130 conifer species and over 400 conifer cultivars. After having cared for them for so many years, I've come to appreciate just how aesthetically, functionally, and ecologically versatile they are. My conifers will be a large part of my legacy, as they will continue to thrive long after I am no longer here. I hope this book will help others to select, grow, and care for conifers. When you plant a conifer, you are contributing to the health of your family, your community, yourself, and the environment.

I am fascinated by conifers. They are some of the oldest organisms on earth. The Great Basin bristlecone pine (*Pinus longaeva*), for example, can live for 5,000 years. Conifers are also some of the tallest, largest organisms on earth. California's magnificent giant redwoods (*Sequoia sempervirens*) can exceed 300 feet and have inspired feelings of spiritual transcendence for millennia. You can experience some of this awe without even leaving the city by simply planting conifers in your urban back yard. Conifers provide a sense of permanence and a feeling of well-being. They add a wonderful dimension to urban landscapes because their forms, textures, and colors contrast with deciduous plants and broadleaf evergreens. Because they vary in size, color, and form, they fulfill many



Ancient bristlecone pine in Great Basin National Park.

David Perry poses for his own remotely-triggered camera in the coast redwoods (*Sequoia sempervirens*) of Jedediah Smith Redwoods State Park.

Conifers have an innate ability to make other plants in their proximity stand out and show up even better. Notice the contrasting forms, colors, and textures among the conifers and the deciduous plants in this image.

roles in the landscape. You can plant conifers in containers, use them as visual anchors in mixed borders, employ them as groundcovers, or make them focal points. Midsize or large conifers can shade hardscapes, frame a vista, screen an unwanted view, back a flower bed or shrub border, function as a windbreak, or buffer sound. In spring, the colors of new conifer growth are especially bright and rich. In summer, their colors soften, letting flowers take center stage. In autumn, their greens and blues glow among the oranges, yellows, and browns of deciduous leaves. They brighten the dark days of winter, and their refreshing, lemony scents are delicious, no matter the season.

Some people think conifers are only firs or Christmas trees, but this vast and varied division contains more than 600 species. Conifers are woody trees, shrubs, and

groundcovers that produce naked (exposed) seeds, usually borne on cones. They are the largest group of nonflowering plants, or *gymnosperms*. Fossil records indicate that these resilient plants evolved more than 300 million years ago, before the Mesozoic Era of the dinosaurs. Much later—around 130 million years ago, in the Cretaceous Period—flowering plants, or *angiosperms*, evolved to have seeds enclosed within fruits.

Despite competition from thousands of different flowering plants, and despite climatic and geologic upheavals, conifers thrive in many regions of the world. Adapted to a wide range of sometimes harsh environments, conifers can grow in the bitter cold and deep snow of high mountains or on a rock wall in an arid region. They can deal with torrential rains and long summer droughts, blasting winds, and waterlogged soil. Because of their wide ecological versatility and their individual adaptability, conifers are suited to almost every garden in many temperate regions of the world.

Atlas cedar (foreground, right), 'Green Arrow' Nootka cypress (far left), and immediately behind it a glowing, golden-larch create a visual feast of form and color that amplify the rich, autumn reds of 'Omato' Japanese maple (center) in the author's garden.

Population growth, rapid urban development, increasing ambient carbon dioxide, climate change, and the loss of ecosystem services to the urban environment result in *urban heat islands.*

Urban areas tend to be 5°F to 10°F (3°C to 6°C) warmer than surrounding, less-developed areas. On warm summer evenings, this difference can reach 20°F. Fossil-fuel emissions, greenhouse gases, air pollutants, the absorption and release of solar radiation by dark-colored roofing and impervious paving, and high energy usage create this excess heat. A lack of trees, which filter the air and shade the ground, exacerbates this problem. Compared to rural areas, cities also have poorer air and water quality, greater noise and light pollution, and higher incidences of health conditions such as asthma and other respiratory illnesses, some kinds of cancer, and ischemic heart disease. Urban gardens help us adapt to and mitigate climate change and the urban heat island effect by providing shade, trapping air pollutants, and significantly cooling the air when they transpire (lose water) through their foliage.

Although adding any kind of flora to your yard—or even your apartment balcony—improves urban environmental quality, adding conifers is particularly effective. Because of their high leaf area index (leaf density) and evergreen foliage, they intercept rainfall and remove pollutants and particulates year-round.

According to a 2010 article, "Influence of Seasonality and Vegetation Type on Suburban Microclimate," outdoor spaces with a high leaf area index have lower soil, surface, and ambient air temperatures. They also tend to have better air and water quality.

Note that both native conifers and site-appropriate nonnative conifers provide similar ecological benefits. These ecological services are beneficial natural processes of healthy ecosystems, such as climate regulation, purification of air and water, and detoxification of environmental pollutants, which serve all

Rush-hour traffic and idling cars create a textbook example of an urban heat island and pollution.

Wind River near its outflow into the Columbia River Gorge. Conifers intercept rain and prevent pollutants from entering the watershed.

living organisms. However, both conifers and broadleaf plants are key components of the urban forest, providing overlapping and different benefits throughout the year. The following list describes the many ways conifers and broadleaf plants, particularly trees, can improve the urban environment.

- **Provide shade** by blocking solar radiation from the ground, pavement, and buildings, reducing the energy absorbed and reradiated back into the air, thereby lowering the temperature of the ambient air, soils, and impervious surfaces. Not only does this directly cool the area, but it also reduces the need for air conditioners and fans (and the factories required to produce them and the delivery trucks to transport them, etc.). This, in turn, reduces ozone-forming chemicals that trap other harmful compounds in the atmosphere in a well-known cycle that raises temperatures and impairs air quality.

- **Cool the air** through transpiration (evaporation through the leaves). In transpiration, plants draw water from the soil, pull it through water-conducting tissues to the leaves, and release it as vapor through *stomata*, tiny pores on the undersides of leaves. Transpiration consumes energy, converting liquid water to water vapor, so it cools the surrounding air. Because deciduous trees have a higher transpiration rate than conifers, they are, in general, better (when they have their leaves) at evaporative cooling than conifers.
- **Take up carbon dioxide** during photosynthesis, converting it into the oxygen we need to breathe and into sugars, which they store in plant tissue, making **conifers** the **largest terrestrial sink for carbon storage** (*sequestration*). Evergreen conifers photosynthesize year-round, removing more carbon dioxide annually than deciduous trees, which lose their leaves annually. Slow-growing, long-lived trees such as conifers can store more carbon over time than other trees. For example, a hectare (about 2.5 acres) of Douglas-fir in the Pacific Northwest can sequester as much as 350 tons of carbon in 100 years, and a hectare of Norway spruce in the mountains of Central Europe has been reported to store about 230 tons of carbon in 120 years. These old forests reach a maximum carrying capacity for their respective regions, and any additional carbon stored is offset by losses to mortality and decay. Thus, leaving a forest to grow to these advanced ages provides a limited one-time increase in carbon storage. In contrast, if the old-growth trees are used in construction, such as building houses and other structures, or used to make wood products, the trapped carbon in the wood remains sequestered, while the area of the old-growth forest can be planted with new trees that can continue storing carbon until they reach maturity. Sustainably managed Douglas-fir forests in the Pacific Northwest, which can be harvested and replanted with conifers on a sustained rotation of about 45 years, transfer carbon from the forest to the sustainable production of wood products as they are being used, recycled, or ultimately transferred to landfills. This process results in a sustainable increase in carbon stores year after year. These managed forests can displace and store about 3 tons of carbon/hectare/year indefinitely. Recycling a portion of the wood can further increase the amount of carbon stored. For example, if 40% of the wood is recycled, over 4 tons of carbon/hectare/year can be displaced and stored. Substitution of wood products for products requiring high levels of fossil fuels in their manufacture, such as steel and concrete, can further reduce greenhouse gas emissions. Sustainably managing conifer forests and effective use of their products can produce a combination of carbon sequestration and carbon emissions reduction and thereby play an important role in mitigating global warming.

- **Absorb other air pollutants,** such as carbon monoxide, sulfur dioxide, ozone, and nitrogen oxides, as well as particulate matter (small airborne particles less than 2.5 micrometers) that foul our lungs and pollute our skies. Because of stomata, grooves, and other foliar structures on conifers' needle-like or scale-like leaves, they are more efficient than broadleaf plants at capturing and filtering small particulates. Their year-round dense leaves also make conifers more effective at removing air pollutants, including ozone, both in winter and during hot, dry periods, when ground-level ozone levels are high. Their bark also intercepts and adsorbs some gases; this is particularly important under very dry conditions, which compromise stomatal activity. Deciduous trees, when in leaf, also remove pollutants.
- **Provide a windbreak**—a physical barrier that slows wind, even in winter. Especially important in winter in colder climates, windbreaks moderate cold winds, reducing cold air infiltration and heat loss from buildings and the consequent need for heating. In addition to cooling buildings in summer, conifers reduce energy usage year-round.
- **Intercept rainfall and absorb water-based pollutants,** which degrade water quality and aquatic habitat. Because it is so dense, conifer foliage intercepts much more rainfall than deciduous trees, which are ineffective at slowing stormwater in fall and winter. When rainfall runs off impervious roofs, roads, and sidewalks, it washes pollutants such as petroleum hydrocarbons, heavy metals, phosphorus and nitrogen from fertilizers, detergents, animal feces, and pathogens into our waterways. Although urban pollutants eventually reach waterways, slowing runoff allows more water-based pollutants to be absorbed by soil and plants. Moderating storm flows also reduces human health hazards from water pollution and flooding, such as waterborne illnesses. This effect is particularly important in regions like the Northwest, which typically experience most storms in fall and winter.
- **Minimize erosion** by anchoring soil with their roots, particularly on slopes.
- **Break up soil compaction** with their roots, lessening flood danger and dust pollution and enhancing water infiltration, rainfall storage, and water availability to other plants. By slowing water infiltration, roots filter pollutants as well.
- **Provide wildlife habitat,** particularly for the birds that enliven our lives, serenade our yards, and help balance insect populations. A yard with some well-chosen conifers—especially natives or site-adapted nonnatives—alongside a diversity of other trees, shrubs, and groundcovers offers food, shelter, and nesting sites to city-dwelling birds, mammals, amphibians, reptiles, and many types of pollinators. Conifer needles and twigs are particularly

Steller's jays preening and courting in a backyard weeping juniper.

important in winter, when other food sources are scarce. Many wildlife species, including songbirds, squirrels, and mice, eat pine seeds. In some areas, pine seeds also feed quail, chipmunks, voles, grouse, wild turkey, deer, bear, and hundreds of species of moth and butterfly larvae. The latter two, along with other needle-eating insects, attract many species of migrating and nesting birds. Then come the predatory birds, such as eagles, hawks, and owls, to prey on those smaller animals. Such is the cycle of life outdoors.

Conifers' dense, prickly foliage helps conceal nests and deter predators. And the shape of many conifers funnels water to the center of the plant, where birds and other wildlife can sip in safety. Pine siskins, juncos, hawks, golden-crowned kinglets, and warbler species are some of the many birds that nest in the dense foliage of hemlocks. Cavity-nesting birds, such as nuthatches, chickadees, owls, and woodpeckers, nest in the cavities they excavate from the soft wood of dead conifers, or they reuse old cavities rather than nest in hardwood trees.

Long-eared owl in a Douglas-fir being harassed by a typically territorial pair of crows.

Piñón pine forest, *Pinus monophylla,* in Great Basin National Park. Inset: Piñón seeds are a valuable food source for humans and a valuable commercial crop. Piñón-juniper ecosystems have had subsistence, cultural, spiritual, economic, aesthetic, and medicinal value to Native American peoples for centuries, and single-leaf piñón has provided food, fuel, medicine and shelter to Native Americans for thousands of years.

- **Provide a food source for people,** as the seeds of many conifers are edible. Most of these edible "pine nuts" are not sold as commercial crops because the size of the seed is too small, difficult to access, or birds and other wildlife eat the seed before it can be harvested. Yet, quite a few species of pine nuts are harvested to provide a local food source. The main source of pine nuts from North America is the piñón pine, chiefly the larger pine nut from the single-leaf piñón (*Pinus monophylla*), native to the American Southwest, and the smaller, milder pine nut from the two-needle piñón (*Pinus edulis*), native to the American West, along with the Mexican piñón (*Pinus cembroides*).

Two Asian pine species, the Korean pine (*Pinus koraiensis*) and chilgoza pine (*Pinus gerardiana*), are widely harvested and exported. The main pine nuts from Europe come from the stone pine (*Pinus pinea*), which have been cultivated for thousands of years. Roasted pine nuts eaten in large quantities by the Australian native peoples are from the Bunya-pine (*Araucaria bidwillii*), while the large seeds of the Japanese nutmeg-yew (*Torreya nucifera*) are sold as a dessert or pressed to make vegetable oil. The inner bark and sap of members of the pine family have high levels of vitamin A and C and many

other nutrients. Strips of the inner bark can be cooked and eaten or dried and ground into a flour for making bread or adding to soups. Years ago, American explorers used conifer bark to treat scurvy. The sap of pine trees can be tapped in spring and drunk as a tea, and young pine needles rich in vitamin C can be steeped to make tea. Protein and vitamin-rich pine pollen can be used as a flour additive and cooked with a large variety of foods.

- **Visually buffer unwanted views,** such as your neighbor's garbage bins or the trash-filled lot across the road.
- **Provide privacy and security** by deterring potential thieves looking for vulnerable houses.
- **Benefit mental and physical health** by providing year-round *green infrastructure* in our yards and our communities. Green infrastructure is an interconnected network of natural and seminatural areas designed to protect and restore natural processes. Urban landscapes are essential for outdoor physical activity and social gatherings, which are causally associated with good mental well-being, cognitive function, and the reduction of chronic stress. Evergreen conifers are especially important for providing these benefits in winter and therefore are an essential part of green infrastructure.

Snow on the variegated needles of the Japanese white pine *Pinus parviflora* 'Ogon'.

Conifers, in general, are more resistant to water stress than broadleaf trees because of several anatomical and physiological adaptations. Like broadleaf woody plants, conifers store water in their trunks, stems, and leaves. Unlike broadleaf trees, however, they have large water storage reservoirs in their sapwood and foliage, and their water-conducting cells refill more readily. Additionally, unlike in broadleaf trees, conifers' water transport system, or *xylem*, exclusively comprises *tracheids* (very small columns of long, narrow cells) that can sustain high tension in the water column and minimize the formation of air bubbles (*cavitation*), which can block water transport. Under extreme water stress, tracheids may allow a small air bubble to form, but they can close off and compartmentalize it, allowing the water transportation to continue.

Conifer leaves have several advantages over deciduous leaves when water is in short supply. Because conifer leaves

Bald eagle perched on a Douglas-fir in an old, established, Seattle neighborhood.

are smaller and narrower than in broadleaf plants, they lose heat more readily. This lowers their respiration and transpiration rates, so they lose less water during drought. A waxy *cuticle* further minimizes water loss by covering the epidermal cells on the leaf surfaces. The stomatal pores are sunken, and they have guard cells that open and close to permit or stop gas exchange. These conserve water during photosynthesis by tightly closing during hot, dry conditions or in freezing temperatures, when water is limited or when photosynthesis is not taking place. As deciduous trees have considerably higher transpiration rates than conifers, they lose more water to evaporation.

It is for all these reasons that we need more conifers in our cities and towns, and, therefore, I wrote this book. Given the horticultural and ecological importance of urban conifers, it is vital that all of us do our part to restore conifers to our urban environment.

Conifer Basics

Chapter 1

From the wind-twisted spruce that tops a rocky embankment to the graceful Douglas-fir that shelters an understory of ferns to the dwarf conifer in the large vase on the patio, there's a conifer to suit almost any setting and purpose. But the choices can be overwhelming. It's well worth taking time to learn the basics of taxonomy, plant features, and specific characteristics before shopping for conifers so you will be able to select the best conifers for your garden.

The Linnaean system consists of a hierarchy of groupings or *taxa*. From largest to smallest groups, the plant taxa are

kingdom → division → class → order → family → genus → species

- A *family* is a group of related *genera* (the plural of *genus*).
- A *genus* is a group of related *species*.
- A *species* is a natural population or group of populations whose form is distinct, and whose individuals can interbreed to produce fertile offspring. A single species is abbreviated "sp." and multiple species "spp."
- A *subspecies* (abbreviated "subsp." or "ssp.") occurs in some species, particularly those distributed widely. Plants earn a subspecies designation when slight but consistent differences are evident in color, height, or form.
- A *variety* (abbreviated "var.") has a consistent trait slightly different from the species. Varieties often occur and reproduce in nature, and most varieties are *true to type*—that is, seedlings will have the same unique traits as the parent plant. For example, *Pinus contorta* has three naturally occurring varieties (sometimes referred to as subspecies): *Pinus contorta* var. *contorta,* the shore pine; *P. contorta* var. *latifolia,* the lodgepole pine; and *P. contorta* var. *murrayana,* the Sierra lodgepole pine. (Note: When the genus is repeated in writing, it may be abbreviated as shown.)

Taxonomy

Taxonomy is the science of plant classification founded by Swedish physician Carolus Linnaeus. It groups plants based on similar key features, which explain how groups of species evolved. Originally, classification was based solely on physical attributes. Since the advent of molecular biology, scientists can inspect an organism's very DNA to classify it.

Cultivar Terms

A cultivated variety, or cultivar (abbreviated "cv."), has at least one attribute, such as leaf color or shape, that distinguishes it from the species and makes it worthy of propagation by plant nurseries. Although some cultivars originate from mutations and others from hybridization of two different plants, a cultivar is selected and cultivated by people. A cultivar is not necessarily true to type—propagating by seed usually produces a plant different from the parents—and often it must be propagated vegetatively, such as by cuttings or grafting.

Understanding these terms will be helpful as you read the text.

- **Provenance:** A local population of a native species that contains genetic variations adapting it to the local environmental conditions.
- **Clone:** An individual that is genetically identical to another individual.

- **Seedling selection:** A chance seedling with unusual desirable traits that someone selects and then breeds for those traits.
- **Witch's broom selection:** A conifer grown from cuttings taken from a *witch's broom*—a tightly congested formation of twigs and foliage due to a genetic mutation that has the characteristics of that witch's broom.
- **Dwarf seedling:** A chance seedling that grows significantly slower than the original plant.
- **Sport:** A stable mutation in foliage color or texture. Many variegated and golden varieties of conifers are derived from sports.

Classifying Conifers

Most plants are given a common name in the language where they are native, and a scientific name that is Latinized. For most people, common names are easier to remember and pronounce, but using common names can lead to confusion or be misleading. Common names contain two or more words; the last word generally denotes the genus or plant group the plant belongs to, and the first word(s) describe the plant. In some cases, however, the common name does not denote the proper plant group, such as the conifers western red-cedar or Douglas-fir. The western red-cedar is not a true cedar, and the Douglas-fir is not a true fir. To alert the reader to those instances where the conifer's common name does not denote the correct genus, a hyphen has been added between the words of the common name.

Plants often have more than one name, even in a single region, and common names, such as *cedar,* are applied to many genera other than *Cedrus,* the true genus for cedars. To avoid this problem, botanists unambiguously give each plant a *binomial* (two-term) name: the genus followed by the species. The genus and species are always italicized; the genus is capitalized, and the species is lowercase. Garden conifers often have a cultivar name, which is not italicized but is capitalized and enclosed in single quotation marks. For example, in the binomial *Pinus contorta* var. *latifolia* 'Chief Joseph', the genus is *Pinus,* the species is *contorta,* and 'Chief Joseph' is the cultivar of the tree commonly known as as lodgepole pine 'Chief Joseph'. Compare how different the cultivar 'Chief Joseph' is from the common lodgepole pine. The common lodgepole has year-round dark-green foliage, and the 'Chief Joseph' has green foliage that becomes brilliant golden in autumn and winter.

Botanists often change conifer classification, and sometimes their names, as new knowledge improves our understanding of conifer genetic relationships and evolution. For this book's purposes, we will use the current classifications and the more-obvious physical traits that you can use to identify conifers in your yard and community. The following section gives you the main identifying characteristics to use in identifying conifers.

Leaves

- **Shape**
  - Narrow needle-shaped leaves, as in the pines (genus *Pinus*).
  - Flattened blades, as in redwood (*Sequoia*), yew (*Taxus*), and hemlock (*Tsuga*).
  - Flat scale-like leaves, as in the genera false-cypress (*Chamaecyparis*), arborvitae (*Thuja*), and true cypress (*Cupressus*).
  - Awl-shaped leaves tapering to a slender, stiff point, as in the juvenile foliage of many junipers (*Juniperus*).
  - Flat strap-like leaves, as in plum-pines (*Podocarpus*), which also have other common names.
- **Cross-section:** For example, spruce (*Picea*) needles have a quadrangular cross-section, and firs have a flat cross-section.

Flat, scale-like leaves in false-cypress (*Chamaecyparis obtusa*) (left), and in arborvitae (*Thuja plicata*) (right).

Flat, strap-like leaves of plum-pine *Podocarpus alpinus* 'Blue Gem'.

- **Attachment:** Where the leaves attach to stems, twigs, and *branchlets* (small branches or divisions of small branches, especially terminal divisions; the term is usually applied to branches of current or preceding year):
  - Needles fastened in tight bundles at the base by a sheath, or *fascicle,* as in pines.
  - Needle clusters radiating out from a peg-like bud without a basal sheath, as on the short shoots of larch (*Larix*) and true cedar (*Cedrus*).

Needle clusters of the true cedar *Cedrus deodara* 'Snow Sprite'.

Needles attached directly to the stem in the Min fir *Abies recurvata* var. *ernestii.*

The spiral needles of Douglas-fir are twisted at their base and therefore appear two-ranked.

- Single needles spread along the branch from a peg-like stalk, as in spruce (*Picea*).
- Single needles attached directly to the twigs and branchlets, as in true fir (*Abies*), Douglas-fir (*Pseudotsuga menziesii*), and hemlock (*Tsuga*).

- **Arrangement:**
  - Opposite, as in dawn redwood (*Metasequoia glyptostroboides*).
  - Alternate, as in bald-cypress (*Taxodium distichum*).
  - Spiral, as in true firs and Douglas-fir, but twisted at the base to appear two-ranked.
  - Whorled, as in juniper.
  - Spiral, as in Japanese-cedar (*Cryptomeria*) and giant sequoia (*Sequoiadendron*).
- **Number in a cluster:**
  - Two, three, or five needles per cluster, as in pine.
  - Greater than five, as in larch or cedar.

Pine needles have two, three, or five in a cluster.

White stomatal bloom on the bottom of the leaves (left to right) western red-cedar, grand fir, and dwarf Hiba arborvitae.

- **Markings:** White bands caused by a waxy coating, or white bloom, around the tiny stomata.
  - Two white stomata bands on the lower surface, as in grand fir (*Abies grandis*), Pacific silver fir, and western hemlock.
  - Two stomata bands evident on the lower surface and one on the upper surface, as in subalpine fir (*Abies lasiocarpa*).
  - Two stomata bands evident on the upper and lower surface, as in noble fir.
  - No distinct stomata bands, as in yew.
  - On lower surface, in the shape of a butterfly, as in western red-cedar.
  - On lower surface, in the shape of an "x," as in Port Orford-cedar.
- **Timespan:** Deciduous conifers, such as species of larch at high altitudes or in subalpine regions, retain their leaves for as little as five months. Other deciduous conifers, including *Taxodium*, *Metasequoia*, and *Pseudolarix*, retain their leaves from spring to fall. Most evergreen conifers retain their leaves for two to six years before dropping them. However, some evergreen conifers are exceptions to this rule. The Pacific silver fir retains its foliage for up to 22 years, and the Great Basin bristlecone pine (*Pinus longaeva*) and some *Araucaria* species can retain their leaves for up to 50 years. Because evergreen conifers lose a small proportion of their leaves annually, they don't need to produce a complete set of leaves each year, helping them succeed on nutrient-limited soils. The oldest interior needles on most evergreen conifers—such as those of pine, spruce, fir, and arborvitae—turn yellow or brown and drop off in the fall, while the remaining leaves at the tips of the branches stay green. The change in needle color and needle drop is a normal physiological response to cooler nights and shorter days. In contrast, some needles on evergreen yews turn yellow and drop in late spring and early summer, when the temperature warms. Old interior needles can also shed because of damage by pests, such as spider mites, which cause yellowish spots or stippling; pathogenic fungi, such as Rhizosphaera needle cast disease; or environmental factors, such as drought and nutrient deficiency.
- **Fragrance:** Many conifers have a distinctive scent when the foliage is crushed.

Branching

- Conifers with whorled branches that form a circular pattern around the central leader or central portion of the tree, such as pines, spruces, true firs, true cedars, and Douglas-firs, have one growth spurt each spring at branch tips and the top of the central leader, from buds formed the previous year. These conifers don't have latent buds on old wood.
- Conifers with a random branching habit, including arborvitae, false-cypress, yew, juniper, and hemlock, have multiple growth spurts throughout the growing season and have many latent buds along their stems.

Cone Position

Some conifers, such as yews and many junipers, have male and female cones on different plants. These conifers are *dioecious* (two houses). However, most conifers, such as pines, bear both on the same plant. These are *monoecious* (single house). Male and female cones

Seed cones in the upper crown and pollen cones below the seed cones in the Korean fir (*Abies koreana*). (This photo was taken at the beginning of May.)

Conifer seed cones come in a stunning variety of sizes, shapes, textures, and colors, providing year-round visual appeal.

of monoecious conifers usually grow on different parts of the conifer and/or become fertile at different times, minimizing self-pollination. For example, pollen cones (male) are often in the mid- to lower crown of the fir, whereas seed cones (female) are in the upper crown.

Pollen is unlikely to float up to the female cones above. This arrangement increases genetic diversity by minimizing self-pollination, as cross-pollination between two plants enhances the species' adaptability to a changing environment. Also, the higher the seed cones are up in the tree, the farther the fertilized seed cones are likely to disperse.

A

B

D

The Korean fir's cones change with the seasons. (Photo A taken in late June, photo B captured in late October, photo C captured in early February, photo D captured in late February after the freezes and thaws of winter, and photo E shows rachises photographed in early May.) All these images except C were taken from the same tree in the author's garden.

Seed Cones

Seed cones are woody and come in a large array of sizes, shapes, and colors. The following traits can help you identify conifers:

- **Shape:** Spherical, egg-shaped, oblong, conical, cylinder, or squashed sphere.
- **Color:** Can change dramatically with the seasons, with a few species exhibiting bright, showy colors in spring. For example, the cones of Korean fir, *Abies koreana*, goes through colorful stages, which is one of the reasons people love to have this fir in their garden. The seed cones emerge purple around May, transform to a bright blue in June, and gradually turn brown in autumn. By the following February, the cones are brown and resinous, and by spring, the old cones fall apart, leaving behind the central spikey rachis, which eventually disintegrates.

C

E

- **Attachment:** Seed cones can be upright on a branch, as in true fir, or pendent, as in spruce and hemlock. In addition, seed cones can be terminal, as in spruce and hemlock, or along the branches, as in true firs, most pines, and Douglas-fir.
- **Size**: From as little as ⅕ inch (1 cm) long, as in the small cones of some junipers and *Microbiota decussata*, to as large as 28 inches (70 cm) in the sugar pine (*Pinus lambertiana*).
- **Timespan:** Cones can persist for only one year, as in the white spruce (*Picea glauca*), or remain on the branch for several years, as in the black spruce (*Picea mariana*). Pines that retain unopened seed cones, such as the lodgepole and whitebark pine, originate in fire-prone ecosystems. These cones open only when exposed to fire.
- **Time of appearance:** Most seed cones first appear in the spring; cedar cones don't appear until late summer or fall.
- **Time of maturation:** In most conifers, seed cones mature one year after pollination. In some conifers, such as cedars, cypresses, and many pines, seed cones mature in two years. In a few pines, seed cones can take three years to mature.
- **Cone scale arrangement:** Arrangement can be *imbricate*, with cone scales spirally arranged and attached along a common axis, with edges of the cone scales overlapping, as in the pine family (Pinaceae), or *peltate*, with cone scales appearing to be attached at a central point and projecting out from that point like an umbrella, as in some members of the cypress family (Cupressaceae).

Cone scale arrangement varies widely in pine seed cones.

- **Cone scale variation in form and size:** For example, cone scales of five-needle pines have a terminal thorny outgrowth, called an *umbo,* in the middle, with no prickle. Three-needle pines have scales with a dorsal umbo and a yellow prickle.
- **Arrangement of bract scales with seed scales:** Bract scales are distinctive in some members of the pine family, such as Douglas-fir, and in many true firs and larches.

The bract scales in the Douglas-fir seed cone look like rat tails and hind limbs.

Scaly seed cones are common in most conifers that grow in temperate climates—the conifers that most North American gardeners grow. Conifers without scaly seed cones include juniper, podocarp (*Podocarpus*), yew, and plum-yew (*Cephalotaxus*).

As in other seed plants, the pollen-producing cones are male, and the seed-producing cones are female. The scales of the seed cones protect the developing seeds.

The seed cones of juniper are often referred to as juniper berries. They are an excellent nutritional food source for wildlife, such as the American robin, when other food sources are scarce in the depths of winter. Juniper berries are also valued by humans, who use them as the predominant flavor ingredient in gin.

Pollen Cones

Pollen cones are herbaceous, smaller, and shorter-lived than seed cones; they usually wither away once they release their pollen. However, pollen cones tend to be much more numerous than seed cones, and they can exhibit conspicuous colors.

Example of attractive pollen cones on *Pinus coulteri x arizonica* at Bloedel Reserve on Bainbridge Island, Washington (top) and on *Abies koreana* 'Horstmann's Silberlocke' (top, page 31).

Pollination and seed dispersal

Unlike flowering plants, which are primarily pollinated by insects and other animals, most conifers are pollinated by the wind. Wind-pollinated conifers usually bear both male (pollen cones) and female (seed cones) structures on the same plant (monoecious). However, some conifers, such as junipers, yews, and most large-seeded pines, need animals for seed dispersal. Animal-pollinated conifers usually bear either male or female structures, but not both.

Wind-dispersed seeds usually weigh less and are more numerous per conifer than animal-dispersed seeds. Lightweight seeds can be carried long distances by the wind. However, large seeds have more stored nutrients for their initial phase of growth before they have the capability to produce their own food through photosynthesis, giving them a competitive advantage over the smaller wind-dispersed seeds. To aid in dispersal, some conifers seeds have wings that allow them to move in a helicopter-like fashion away from the tree. Some wings are firmly attached, as in five-needle pines, and some wings are loosely attached, as in three-needle pines. Seed cones open when the weather is dry, and close when the weather is wet to ensure that the seeds will be well dispersed—dry seeds fly much farther than wet seeds. Because wind pollination is inefficient, conifers need to produce and disperse billions of tiny pollen grains into the air, where they float and find their way to the ovule of a female cone for fertilization. However, only a lucky few of the pollen grains will encounter and enter an ovule of the same species and initiate fertilization. Broad seed dispersal helps conifers reach specific habitats that are favorable to survival and allows conifer species to migrate to new habitats, which is important for the species to adapt to a changing climate.

Buds

Buds are small new growths on the sides or ends of a branch in the form of protuberances on the stem that develop into a leaf or shoot. Some conifers, such as cypress, juniper, and arborvitae, lack distinguishable buds.

- **Shape:** Globose, ovate, round, cylindrical, spindle form, acute.
- **Bud scales:** These specialized protective leaves surround the buds of certain plants, either loosely covering or tightly appressed, at the apex straight or curved backward at the tip, with or without resin, and with hairs (e.g., the elongated buds sheathed in silky white hairs of *Pinus thunbergii*) or without hairs.

Twigs

- **Texture:** Smooth-surfaced without projections, as in firs, or rough-surfaced, with woody peg-like projections, as on spruce branches and the short shoots of true cedars and larches.

Bark

- **Texture:** Exfoliating in strips or in patches, scaly, furrowed, smooth or rough. In spruce, rough and scaly; in fir, smooth and furrowed.
- **Color:** Gray, brown, green, white, orange, or red—or a combination.
- **Thickness:** Conifer bark is generally thick, which provides protection from fire. For example, the bark of the giant sequoia (*Sequoiadendron giganteum*) can have bark more than 20 inches thick to protect it from fire.

Trunk Shape

- Swollen at the base, as in bald-cypress.
- Fluted and buttressed, as in dawn redwood.
- Nearly cylindrical with little taper, as in giant sequoia or Sitka spruce.
- Obvious taper, wider at the base and smaller at the crown, as in most other conifers.

The fluted and buttressed trunk of dawn redwood.

Well-fortified with all this botanical information, we will explore the conifer families and their geographical distribution and key features in the next chapter. Nearly all the temperate genera have the potential to be used in a sustainable garden.