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The urban jungle and allergy

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The term *urban jungle* denotes the biologic assemblage that is established in urban and suburban areas as these areas develop. Included in this assemblage are all of the plants, animals, insects, and other life forms that inhabit urban zones—many of which thrive solely because of the activities of humans. Although this article examines the botanical aspects of the urban jungle, it is reasonable to include such organisms as house dust mites and cockroaches in the broader application.

A major component of the urban jungle is the urban forest—the assemblage of trees, shrubs, and other plants that occupy the urban and suburban zones. Many of these species, planted in abundance by humans, produce powerful allergens that exist in high numbers. The overriding theme of the urban jungle is that it is an artificial structure that exists solely because of the activities of humans.

Concentration of people in urban areas

To understand the implications of the urban jungle on allergy, it is helpful to examine the demographics of urban zones. Approximately 75% of the US population lives in urban areas. More than 50% of US residents live in the 39 largest metropolitan areas, which have more than 1 million people. Ninety percent of the country's growth is occurring in urban areas [1,2].

Many cities in the United States are growing rapidly. With growth and development comes the expansion of the urban jungle. Between 1980 and 1990, Fresno, California, grew by 63%, and Virginia Beach, Virginia, grew by 50%. Other rapidly growing cities include San Diego, California (26%), San Jose, California (24%), Phoenix, Arizona (25%), Austin, Texas (35%), and Charlotte, North Carolina (26%) [1,2]. This development requires the planting of acres of new vegetation—some of which is highly allergenic and positioned close to susceptible individuals.

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With these trends toward urbanization, distribution of the human population increasingly favors the development of allergies to unnatural vegetation assemblages rather than allergies to naturally occurring forests and prairies.

Human behavior and exposure

Once the urban jungle is established, its importance to allergy goes hand in hand with human behavior. People's activities and places of activity within the urban zone set up exposure relationships that result in sensitization and subsequent reactivity.

The everyday patterns of human behavior dictate that most people spend about one third of the day at work or school and traveling to and from these places. The activity of moving from home to work or school results in exposure to a number of environments that have a variety of allergens in amounts that might not be encountered without this traveling. People also spend about one third of the day performing activities at home, in the yard, or in business and recreational areas, such as shopping malls and parks. The extent to which these activities cause a person to move through diverse environments directly relates to the diversity of allergen exposure. One third of the day usually is devoted to sleeping; although this activity involves exposure to a more restricted environment, exposure to house dust mites, molds, and pet danders often occurs in bedrooms.

Availability, allergenicity, and impact

The importance of an aeroallergen is a function of its availability and allergenicity. The most important allergens in the urban environment are available and highly allergenic.

Availability of an allergen determines the extent of exposure for individuals and for whole communities. It is not uncommon to find that some individuals develop sensitivity to a plant species in their yards (high availability), but sensitization to this species does not occur in anyone else in the community (low availability).

Allergenicity also affects the development of sensitization to an allergen. Although allergenicity has not been quantified across the allergen spectrum, clinical observational data suggest that not all allergens are created equal (eg, ragweed and Lamb's quarters are more allergenic than apples and magnolias).

Development of the urban jungle

Availability and allergenicity set up the exposure and patient reaction to an allergen, and these elements are largely the result of conscious human choices made during development of the urban landscape. In the initial stage of development, all existing vegetation is removed to construct buildings and infrastructure. This step involves a considerable amount of earth moving and sculpting of the land.

Development is a planning and architectural function during which buildings and improvements are installed, after which new vegetation is planted. The choice and installation of new landscaping is a critical point in terms of allergy exposure. The allergy potentials of trees placed in new streets and parking lots and of other landscaping is seldom considered in the design phase. Numerous references are devoted to helping developers make these vegetation choices, but these references do not consider allergy implications and often suggest allergenic plants. [3–11]. Most of the major allergenic tree species show up on suggested planting lists.

The result of urban development and associated planting is well documented—nearly every city has a planting ordinance and a list of recommended species. The last half of the 20th century was marked by extensive planting of trees in urban areas throughout the country, which was part of the overall “greening of the planet” [10].

Concrete jungle to emerald city

Many cities that had been known as concrete jungles dramatically transformed their environments with campaigns to reforest their neighborhoods. In Los Angeles, Tree People, a tree advocacy group, planted 1 million trees in the years before the 1984 Summer Olympics. One million trees are estimated to cover an area equal to 400,000 single family homes [11]. Many of the trees that were recommended for planting in Los Angeles are allergenic trees. The pollen load in the urban atmosphere from 1 million trees likely is considerable and will increase as the trees grow larger.

Tree advocacy groups are common throughout the United States; every state has at least one of these groups [12]. Communities throughout the country are developing urban forest programs.

Seattle (also called the Emerald City) is known for its lush urban forest of parks, gardens, green belts, and street plantings, almost all of which were developed in the last half of the 20th century. Seattle is now growing its second or third city forest. The city originally was densely forested with spruce trees and Douglas firs, which were removed as the city developed and were used for lumber or firewood. Seattle’s first mayor owned a sawmill. Seattle is now a city of street trees, most of which were planted after 1920. The urban forest is a diverse mix of species; the more common species include Sweet gum (13.5%) and Norway maple (13%), both of which are allergenic and were introduced to the region. The top genera of street trees planted in Seattle also include other maples, linden, and oaks. Pioneer Square, a major downtown mall, is forested in sycamore [13].

Seattle ranks second from the bottom—tied with Indianapolis—in terms of forest cover among 20 major cities inventoried. It has 27% tree cover within its greater city limits. In comparison, Los Angeles has roughly 50% coverage; Newark, New Jersey, has 62%; Chicago has 63%; and Boston has 69%. Los Angeles claims to have more than 10 million trees in its urban forest, encompassing 465 square miles. In Los Angeles, an average of 5000 new trees are planted in public spaces each year [14]. Most cities are following this tree-planting trend.

Pollen–patient relationships

Having described the general scope of the urban jungle it can then be summarized that the urban environment sets up a high diversity of plant species in high numbers (concentration) and intermixes them with a dense human population—a portion of which is susceptible to allergies. An average person going about their business in an urban environment is in and out of one exposure situation after another—some moderate and some extreme. A person in close proximity to a blooming tree may be exposed to pollen counts of 10,000 particle per cubic meter of air and upward. A person who has two alder trees in his back yard is in close proximity to an allergen source releasing approximately 14 billion pollen grains into his immediate environment over a two week period (Bayer Corporation, Allergy Division, unpublished data). In Las Vegas in 1999, the airborne pollen level directly under a male mulberry tree was greater than 65,000 pollen grains/m³ of air [15].

Pollen dispersal tests on typical landscape trees, such as oak, maple, birch, and poplar, consistently have shown that 99% of the source plant's pollen falls out within 30 feet of the plant's drip line [16]. It has been estimated that a single tree in close proximity exposes an individual to 10 times more pollen than does a similar tree located down the block. Although air currents disperse much of these pollens, closer proximity to the source results in greater total exposure. In an urban environment, many sources are located next to each other, and people are distributed throughout this environment.

Pollen amounts that cause allergic reactions

It generally takes about 30 pollen grains/m³ of air to bring on an allergic reaction. In one British study, all of the grass-sensitive patients reacted at 50 pollen grains/m³ of air. An average person inhales about 10 m³ of air/d, resulting in inhalation of approximately 300 to 500 pollen grains/d (30–50 pollen grains/m³), which would sustain an allergic reaction. A 10-fold increase in the reactivity threshold would still be small compared with the amount of pollen produced.

Pollen production

An anther, the organ of pollen production, can contain a varying number of pollen grains, ranging from 2 to more than 60,000. Anthers from Norway maples contain 1000 grains, apple-tree anthers contain 1400 to 6200 grains (depending on the species), and anthers from European Excelsior ash trees contain 12,500 grains [17].

Determining the pollen load of an area using the number of pollen grains per anther is somewhat misleading, in that the load is based on the number of pollen grains per anther, multiplied by the number of anthers per flower, multiplied by the number of flowers per tree, multiplied by the number of trees in the area. Further adjustments are needed to account for the fact that not all flowers release

their pollen at the same time and that the volumes of released pollen are dependent on environmental factors, such as wind, humidity, and temperature.

Even when the most superficial equation is used to determine a tree's pollen load, the number of pollen grains escalates rapidly. The number of grains produced per flower may reach 8000 in maple trees, 57,000 (3 anthers $\times$ 19,000 grains per anther) in Cereal rye, and 180,000 (6 anthers $\times$ 30,000 grains per anther) in Sheep sorrel. Corresponding figures for pine, juniper, and spruce trees are 160,000, 400,000, and 600,000, respectively [17]. There is considerable difference between the pollen production in wind-pollinated plants (higher production) versus that in plant pollinated by other mechanisms.

Species that produce the highest number of pollen grains include trees that have catkin-type inflorescence, which is designed for wind pollination. Many of these genera commonly are found in urban streets, yards, and parks. A catkin is an inflorescence of numerous male (pollen-producing) flowers (up to about 200). The approximate number of pollen grains produced per catkin is 6,000,000 for birch trees, 4,500,000 for European or Black alder trees, 3,900,000 for European hazel trees, 1,250,000 for English oaks, and 175,000 for European beeches [17].

Few attempts have been made to calculate the amount of pollen produced by whole trees. Erdtman presents data from a period of more than 50 years. Using these data, the average yearly production of pollen grains per tree was estimated (Table 1).

Plants produce different volumes of pollen in different years as a response to environmental factors, and different genetic strains of the same species may produce different amounts of pollen. In terms of aerobiologic sampling, and especially in urban forests, the pollen count is sensitive to the relative density of the species distribution in a given area and to the distance to the nearest tree from the person taking the sample.

At a pollen count of 500 pollen grains/m³ of air, a sedentary individual outdoors, is calculated to inhale about 7200 pollen grains/d, assuming that the pollen count stays the same over time [18]. This amount is much smaller than the 7,240,000,000 grains per season that could be released by the alder tree in a given front yard.

Table 1
Average amounts of pollen production for selected species

Tree species	Pollen production (pollen grains/year/tree)
European beech (<i>Fagus sylvatica</i>)	409,000,000
Sessile oak (<i>Quercus petraea</i>)	654,400,000
European hornbeam (<i>Carpinus betulus</i>)	3,149,300,000
Spruce (<i>Picea abies</i>)	5,480,600,000
European White birch (<i>Betula alba</i>)	5,562,400,000
European hazel (<i>Corylus avellana</i>)	5,603,300,000
Little-leaf linden (<i>Tilia cordata</i>)	5,950,300,000
Scotch pine (<i>Pinus sylvestris</i>)	6,442,200,000
Alder (<i>Alnus</i> species)	7,239,300,000

Urban allergy exposure and modes of pollination

Pollination can be accomplished in a number of ways. Common modes of pollination include wind (anemophily), insects (entomophily), and birds (ornithophily). Pollen transfer by bats (chiropterophily) or water (hydrophily) are relatively uncommon and are of no significance to human exposure. Amphiphily, pollination by wind or insects (and usually both), is discussed because of its importance to human exposure.

Modes of pollination are important because they determine the likelihood and potential volumes of pollen that will be contributed to the air. Wind-pollinated plants tend to produce larger quantities of pollen compared with plants that are not pollinated by the wind; because of this larger release, quantities tend to be distributed in measurable amounts over larger areas. Plants that pollinate by water liberate little if any pollen into the air.

Wind dispersal of pollen

The anthers of wind-pollinated plants usually are suspended from the flower by long filaments, producing a stamen that is exposed wholly to the influence of air currents. (Other major characteristics of this group of plants can be found in numerous references [17,19,23].) In catkin-type inflorescences, whole, reduced flowers are exposed to air currents, and the anthers, which usually have short filaments, are exposed fully to the drying action of air currents.

The nature of the vegetation assemblage within which wind pollination occurs is another important variable that affects the traveling distance and concentration of pollen. Not all of the pollen that is released into the air reaches the flowers of other members of the species. Leaves, branches, trunks, mosses, and lichens serve as physical obstacles to pollen air transport, and a considerable amount of pollen is lost through impaction on such surfaces. The importance of this filtration process was suggested and quantified by Tauber [20–22], who noted that in deciduous forests, leafing results in the production of many surfaces that tend to intercept airborne pollen and significantly lower the airflow velocity. In urban forests, it is reasonable to assume that similar filtration mechanisms are at work.

Pollination by insects

Much research has been published about the relationships between flowers and the insects that pollinate them. Insect-pollinated plants often are not considered to be important allergenic pollen producers. Although these plants, compared with wind-pollinated plants, tend to release smaller quantities of pollen into the air, mostly through leakage and disturbance of pollen by foraging insects, the plants often are placed close to human habitation because of their ornamental qualities, increasing the availability of their pollen. Many plants that are categorized as insect-pollinated species often are not pollinated strictly by insects. Some plants from which insects collect pollen for food are actually wind

pollinated by design (eg, alder, birch, pine). Also, many plants that are visited by insects may be simultaneously releasing pollen into the wind. Such plants are described as amphiphilous, a characteristic of great importance to the development of allergies, especially in the urban environment.

Amphiphily

Some typically entomophilous plants produce abundant pollen, have exposed anthers because of an open floral morphology, have less sticky pollen, and can release moderate amounts of pollen into the wind [23]. These amphiphilous species often are adapted partially to wind dispersal as a secondary mode of pollen transfer. Lewis and colleagues refer to these species as facultatively anemophilous [23]. Other species accidentally release pollen into the wind, and the volume of released pollen for these species is less than that for fully anemophilous species.

Allergy literature has a tendency to consider species that are not wholly wind pollinated to be insignificant, which can be misleading. Even entomophilous plants, when concentrated in the immediate vicinity of a susceptible individual, can release enough pollen into the air to cause allergy. This observation is important when considering the confined spaces and proximate exposure environments of urban settings.

Thompson's law

Regardless of the mode of pollination, one simple test usually sufficiently indicates a flower's likelihood of releasing pollen into the air. If a flower type produces stamens in which the anthers project outside of the protecting structure of the flower (ie, the anthers are easily visible), there is a good chance that pollen will be released on air currents, with or without the assistance of insects or other agents. As discussed earlier, other factors that determine the volume of released pollen include the number of pollen grains per anther, the number of anthers per flower, the number of flowers per plant (size of plant), and the commonness of the species to a geographic area, including its proximity to human population. Proximity is a key element in examining pollen exposure in urban areas.

Pollen dispersal on air currents

The physical factors that influence particle dispersal on air currents are the same factors that determine which pollens and the quantities of pollens that will impact allergic individuals in urban settings.

At the simplest level, pollen transport involves an interaction between two variables: the settling velocity of the pollen and wind velocity. Settling velocities govern pollen removal from the air stream, and wind velocity keeps particles entrained in the air stream. Pollen terminal velocities range from 2 to 6 cm/s, whereas average wind velocities within most plant communities, urban or

otherwise, range from 1 to 10 m/s [20,24]. In general, pollen dispersal increases as wind velocity increases and as settling velocity decreases.

Stokes law dictates that the steady-state settling velocity for spherical objects in the size range of most pollen grains (20–40 μm) is proportional to pollen size (diameter) and density (mass/volume). Pollen density is variable and depends on exine thickness and structure and water content of the pollen grain.

Numerous investigators have demonstrated that pollen concentration downwind from an elevated source drops rapidly at a rate that is inversely proportional to the square of the distance between them [20,25–27]. The concentration gradient is influenced by atmospheric turbulence, which is controlled by surface roughness, wind shear, and vertical temperature profile [28]. A highly unstable atmosphere with high turbulence favors a high atmospheric dispersive capacity, and the pollen concentration declines rapidly with distance from the source. Most of these factors are at play in urban areas, where buildings and other structures modify natural airflow.

The physics of pollen release and dispersal indicate that small, light grains disperse readily and that dispersal distances are greater in situations characterized by higher wind velocities. Such simple conditions seldom exist. Higher wind velocities often are accompanied by higher turbulence, and the atmospheric load downward from the source decreases more rapidly under such conditions. Many variables, both concurrent and sequential, influence the dispersal of pollen on air currents. In urban zones, obstruction of air currents breaks up atmospheric flow into pockets that may vary from local area to local area.

Regional distribution of pollen

The relation between the pollen entrained in the atmosphere and the diversity and distribution of pollen-source plants is important, because pollen identification and numerical occurrence relate to human environmental exposure. One of the principles of the study of pollinosis is that the plants that produce the offending pollens tend to have identifiable regional distributions and ecologic habitats. This concept extends to the urban environment, where certain plants are zoned depending on the nature of the developmental history, quality of care, and age of the locale or neighborhood under consideration. Some of the early allergy literature describes the impact of the suspected allergenic pollens on particular regions, and studies that discuss local and regional aeroallergens have contributed greatly to the understanding of allergy exposure.

As the list of clinically confirmed allergenic plants became more complex, the information about these plants tended to be generalized. The allergy literature is riddled with botanical inaccuracies and overgeneralizations to the extent that it is difficult to locate botanical and aerobiologic literature that is applicable to an allergist's local practice. The regional differences in allergenic plant distribution

and airborne pollen distribution can be approached from the perspective of vegetation distribution and of patient exposure.

Natural distribution of plants

In natural vegetation, various plant species tend to occur in a geographic area that can be delineated by a boundary or transition zone. In all parts of the world, there are geographic areas of plant species with uniform and distinctive plant assemblages. These large distributional units are referred to as floristic provinces [29]. North America can be divided into 10 floristic provinces that each have a unique assemblage of plants—many of these plants are known to be allergenic. Floristic provinces constitute the largest classifications of vegetation that have allergic significance. Such large divisions are of significance to a local allergy practice in only general terms.

The eastern deciduous province contains forests with various maples, beeches, basswood (linden), oaks, and hickories—all of which are known to be allergenic. Although the distribution of the individual species fits within the boundaries of the floristic province, the species are not distributed homogeneously. The distribution of these species is dependent on habitat, which accounts their varying densities at different points in the province.

In every floristic province, there are numerous species, usually one half to three quarters of the total flora, that occur naturally in no other floristic province. These species are said to be endemic to the province. Some endemic species only live in specific habitats, making them rare by virtue of the scarcity of their specific habitat. Data on floristic province assemblages apply only to the natural distribution of plant species.

Although silver maple (*Acer saccharinum*) is endemic to the eastern deciduous forest province, this fact does not determine the species' range of allergenic significance. Endemic species often are planted as ornamental plants and grow well outside of their provinces. Silver maple is one of the most widely planted shade trees throughout North America, and its greatest concentrations are in urban and suburban zones. Almost all of the significant allergenic trees that are native to Europe occur in North America as trees in streets, parks, and yards.

Unnatural distribution of plants

Species of plants that are characterized as unnaturally distributed in contrast to the native vegetation fall into two categories: weeds and purposely planted ornamental plants (including crops). Weeds and ornamental plants share several characteristics:

- They exist in response to human impact on the land.
- They usually have their greatest concentrations in populated areas.

- They tend to be introduced to an area from another floristic province or continent.
- Their allergenic members tend to adversely affect allergic individuals by virtue of their large concentration of plants (and their pollen) in a relatively small area or by proximity to human occupation.

Weeds

The term *weed* has become ambiguous—especially as it applies to allergy. Historically, allergenic plants have been subdivided into trees, grasses, and weeds; however, many grasses and some trees actually fit the definition of a weed. Some crop plants can become weeds when they grow where they are not wanted. Orchard grass is a weed grass throughout much of North America, but in parts of the Pacific Northwest, where thousands of acres are grown for seed, it is a crop plant. Many common allergenic weeds in the North America were introduced as food plants or medicinal herbs.

A weed is a plant that is not sown intentionally, whose undesirable qualities in a given location outweigh its good points. The term *weed* more correctly describes an ecologic situation than a botanical type. For the purposes of allergy and its associated aerobiology, the term *weed* has come to denote a nongrass, nontree species that grows in the wild and produces enough airborne pollen to be allergenic.

Weeds are a broad classification of plants that tend to follow and remain closely aligned with human activity. They are in close proximity to humans and produce their highest pollen counts near humans. As allergenic plants, they tend to exist in great numbers covering large areas, exist sparingly but produce copious quantities of pollen, or both. Short ragweed tends to grow in large numbers (sometimes acres of plants) and produces large quantities of pollen. A single ragweed plant releases about 1 billion pollen grains during a single season. It has been estimated that ragweed releases a million tons of pollen in the United States each year [30].

Weeds, in general, do not conform to natural vegetation patterns, but instead conform to the density of human activity, because such activity causes disturbance of the soil and disruption of the stable native vegetation patterns. In and around urban areas, which have concentrations of disturbed land, allergenic weed species often are the first plants to colonize the land. Depending on the section of the United States, such diverse allergenic species as Mugwort sage, ragweed, English plantain, dock and sorrel, Lamb's quarters, pigweed, and various grasses tend to become established quickly. These and other species become dense and prosperous in most instances and may be replaced over time by tree and shrub species in the absence of further disturbance. Urban weeds can be classified into two groups by the nature of the property on which they occur. In most cases, as property transitions from one type of use to another, the weed flora changes accordingly.

Annual disturbance weeds

On property where the soil profile is disturbed mechanically every year, an assemblage of annual weeds—many of which are highly allergenic—grow. These annual disturbance weeds complete their life cycles in 1 year and set seed for the next year. Annual mechanical disruption of the soil profile is required to maintain the assemblage from year to year. Annual disturbance weeds of allergic importance include Short ragweed, Lamb's quarters, Kochia, Russian thistle, Redrood pigweed, Velvet grass, and Annual bluegrass.

Infrequent disturbance weeds

On waste sites where disruption has ceased, the weed flora transition to infrequent disturbance weeds (eg, Yellow dock, Western ragweed, English plantain, Mugwort sage, Sheep sorrel, Orchard grass, Tall fescue). These species are intolerant of annual disruption and generally require 1 year of vegetative growth before they flower.

Under nearly ideal conditions, a piece of disrupted property transitions from annual disturbance weeds to infrequent disturbance weeds to grassland and eventually back to trees and shrubs. Because ideal conditions rarely exist, the succession of vegetation types usually is accomplished by a series of starts and stops, and new disruption results in a return to the first stage—annual disruption weeds. Many plants in the families that characterize annual disruption weeds have a tremendous capacity for long-term seed viability when buried in soil (some of these plants are viable for upward of 60 years). After a grass field has been plowed under, it is not uncommon for the land to produce a vigorous crop of Lamb's quarters, pigweed, ragweed, and other annual weeds the following season.

Trees as weeds

Another element of the urban forest that is important to allergy is the adventive trees, such as Black walnut, Tree of Heaven, Siberian elm, Boxelder, Eucalyptus, and Black locust. These tree species escape cultivation and freely seed into vacant land. The weed trees rapidly escalate in number and can thrive under adverse growing conditions, adding to the allergenic pollen load of the community. In most of the urban areas of the United States, Tree of Heaven is a common weed tree in the less maintained parts of the cities. In Providence, Rhode Island, there are virtual forests of this species.

Ornamental plants

The second class of unnaturally distributed plant species is the ornamental plants, which are planted in close proximity to human populations. Allergenic ornamental species tend to have a greater impact on susceptible humans than their numbers might indicate.

In allergy literature, ornamental plants often are not considered to be important sources of aeroallergens. Although this theory is partially true, there are many exceptions. Ornamental plants of one area are the native plants of another area, and

none should be considered nonallergenic. As noted earlier, any plant that has stamens that project above the surface of the flower contribute some pollen into the air stream. The plant's allergenic impact also depends on how much pollen is produced (availability), the pollen species' allergenicity, and the exposure relationship between the pollen and a susceptible individual. Because ornamental plants are planted close to human occupation, their exposure potential is maximal.

Ornamental plants include trees, grasses, shrubs, and herbaceous species that are planted in varying concentrations around centers of human activity. These species usually are introduced from some distant geographic zone and exist in their new environments because special habitats are created for them. The ornamental plants that affect allergic individuals often are not numerous enough or homogeneous enough to register on centralized single-station pollen samplers, so they never show up on community surveys. To accurately assess the presence of these plants in aeroallergen surveys, transect sampling methods need to be used.

The impact of an allergenic ornamental on an allergic individual is proportional to the individual's distance to the pollen source; this impact varies with the amount of pollen produced. A large anemophilous tree in a residential yard can produce enough pollen to contaminate at least a half of a city block.

In the somewhat restricted environment of an urban setting, a single tree in reasonable proximity to a sensitized individual can produce enough pollen to elicit a reaction, even when correction factors for the extended length of the blooming period and atmospheric dilution are considered. The problem is compounded when numerous trees of the same species are concentrated in a small area, as in the case of a street lined with ornamental oaks, sycamores, maples, or lindens. Such species usually are not characteristic of the surrounding floristic province.

Most allergists have not had the resources to properly ascertain the ornamental flora of their professional practice area. Many articles that have been published on allergenic floras disregard the presence of ornamental species, even though these same species are recognized as allergenic in the distant floristic provinces from which they originated.

In clinical allergy, clinicians often use a standardized regional approach to diagnosis and treatment rather than considering a patient's possible reaction to three or four exotic species in addition to a reaction to the regional forest species. The impact of localized allergens may be important to the priming effect that the allergens may exert on individuals with seasonal allergy [31]. Exposure to high concentrations of a localized pollen may increase the allergic response to lesser concentrations of a pollen with a more regional identity.

Patient exposure to allergenic plants

The preceding examined the natural and unnatural aspects of plant distribution as they pertain to the occurrence of allergenic plants and their associated pollen. This section shifts emphasis to human exposure to allergenic plants in the urban

environment and how this type of exposure relates to an allergic individual's daily routine.

In aerobiology, various stationary air sampling tools are used to sample particulates that are brought to the site by air currents. Human aeroallergen exposure differs in that allergic individuals are not stationary but rather move from site to site while performing their daily activities. Human aeroallergen exposure is the sum total of all the various environments that the patient has passed through in a given increment of time, whereas the air sampler is limited to what occurs in a single environment during the same time interval. A sampler supplies a complete documentation of exposure in a single environment. A nonsedentary individual, operating during the same time interval, selectively samples a variety of environments.

Human behavior can be generalized into a series of socioenvironmental habitats that each potentially has its own assemblage of aeroallergens that may differ over time—even hour by hour. Socioenvironmental habitats that account for much of an average person's operational pattern on a daily, weekly, or monthly basis include, but are not limited, to the following:

Residential

Home

Yard (landscaping)

Adjacent property

Street trees of neighborhood

Commercial or vocational

Shopping areas

Parking areas

Work environment

School environment

Transitional

Travel routes

Recreational

Parks

Vacation areas

In most cases, application of patterning in patient behavior is more predictable than one might assume. Most people fall into patterns of behavior that dictate their movements throughout the day. People usually have adopted a route to and from work, park in the same area, and walk the same routes from car to work, school, or other activities. Human behavior is so patterned that a language to describe departures has been adopted. Modification of a usual pattern of behavior, like stopping by the dry cleaners on the way home from work, is referred to as "going out of the way."

Although it is poorly documented because of the lack of appropriate equipment and protocols, human behavior is greatly related to allergen exposure in urban environments, where individuals might confront dozens of small,

localized exposure environments in 1 day. Most people probably travel to a pollen exposure environment equally as often as the pollen blows in on the wind. Clinicians must tell their patients about the importance of behavior in pollen exposure to help patients understand how to develop avoidance procedures.

Allergy-free landscaping as an avoidance mechanism

Although the discipline of studying and quantifying localized pollen exposure environments for individual patients is in its infancy, one area that shows promise is the development and application of allergy-free landscaping. With the growing concern about the effects of high exposure to allergenic landscaping, there is a small but determined effort to identify nonallergenic or low-allergenic alternatives. Although these efforts do not nullify the allergic effects of the urban jungle as a whole, they may point the way to a solution for a patient's immediate environment. Keeping major allergenic plants out of the home environment reduces much of the allergen exposure in that environment; however, the best efforts of a homeowner can be cancelled out by the actions of neighbors.

Because each patient's immune system reacts differently to the variety of airborne pollens, it is impossible to identify all of the species that initiate an allergy, and no plant is nonallergenic; however, there has been a major step forward in analyzing the allergy potential of landscape plants.

Ogren Plant Allergy Scale

The Ogren Plant Allergy Scale (OPALS) subjectively measures the allergy potential of garden and landscape plants, including street trees. It uses a 1- to 10-point ranking system that is based on 70 individual factors (not all factors apply to each plant) [16]. The safest, least allergenic plants are ranked at 1, and the worst, most allergenic, plants are ranked at 10. Some samples of the system include the following:

1. A completely pollen-free tree, like Red maple, variety Autumn Glory, ranks at 1—the best. Autumn Glory is a vegetatively propagated tree that produces no pollen.
2. Double-flowered Hollyhocks are ranked at 2, and single Hollyhocks are ranked at 3. Single Hollyhocks produce more pollen than double-flowered varieties, and the species is not known to cause allergies in the general population.
3. Among shrubs, Abelia ranks at 5, whereas Japanese boxwood is ranked at 7. Few people realize that boxwood has flowers that cause allergy unless the tree is kept closely clipped.

4. At the high end of the scale are Bottlebrush (ranked at 9) and staminate Peppertree, the most allergenic species (ranked at 10).

More than 5000 plants have been evaluated using the OPALS. The scale is built on the foundation of two fundamental questions: (1) What do plants that are well known to cause allergy have in common with each other? (2) What do plants that are known not to cause allergy have in common? Using these two questions, large sets of allergy criteria were established, one set with positive values and the other with negative values.

Allergy potential rarely has been an issue when choosing street trees and shrubs, because there has not been a reliable method for making this determination. Within the same species of tree, certain cultivars rank at the bottom of the scale, and others rank at the top. Some cultivars are sterile and produce no pollen. The OPALS system is not perfect; however, it represents a major step forward.

Beneficial effects of urban forests on respiratory disease

In contrast to the allergy problems caused by dense tree cover in urban forests, there are also benefits derived from planting trees in urban environments. There has been considerable interest in the health implications of fine particles in the atmosphere. Particulate matter with aerodynamic diameters of less than 10 μm is the standard measure of this form of air pollution. High concentrations of particles less than 10 μm in diameter have been linked with increased severity of respiratory illness. The smaller particulates of 2.5 μm or less are considered to be very damaging to health, because they more easily can penetrate the respiratory tract. In the urban environment, as much as 80% of emissions of these smaller particles come from road traffic.

Research has shown that trees act as biologic filters, removing large quantities of particulates from the urban atmosphere [32]. As much as 234 tons/y of particulate matter are removed in the Chicago area by trees [33]. This filtering largely results from the large leaf area of trees relative to the ground area on which they stand and from the physiologic properties of the leaf surfaces (eg, presence of leaf epidermal hairs or waxy cuticles on leaves of some species). Interception of particles by vegetation has been shown to be much greater for street trees because of their proximity to high intensities of road traffic [34].

The urban forest is also effective in removing chemical pollutants from the air. Ozone, chlorine, fluorine, sulphur dioxide, carbon, and other gases are absorbed by trees. Each city tree removes about 6 kg of carbon dioxide from the atmosphere per year.

The typical person consumes about 386 lbs of oxygen per year. A healthy tree can produce about 260 lbs of oxygen annually—two trees can provide the oxygen needs of a person for 1 year [35].

Summary

The urban forest is the assemblage of trees, shrubs, and other plants that occupy the urban and suburban zone. In urban areas, the number of potentially allergenic plants has grown rapidly as the diversity of plants increases. The recommended street trees of many cities are allergenic species that are well known to allergy clinicians.

Some of the most commonly planted trees in urban zones are known to be the greatest producers of pollen. These trees are situated in close proximity to humans, either at home, at work, or on their travel routes between locations.

There are common misconceptions about the plants that do and do not cause allergy. It generally has been considered that insect-pollinated plants with showy flowers are allergy safe; however, when these species are planted in close proximity to people, as they are in urban landscaping, the pollen that leaks from the flowers is often enough to cause an allergic reaction. With increasing emphasis on green space in urban areas, it is advisable to evaluate what is being planted, how much is planted, and the plants' potential for triggering allergy.

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