

## **Common Allergenic Pollens, Fungi, Animals, and Arthropods**

***Robert E. Esch\*, Cecelia J. Hartsell,  
Rodger Crenshaw, and Robert S. Jacobson***

*Greer Laboratories, Inc., P.O. Box 800, Lenoir, NC 28645*

### **Pollens (1-4)**

Certain plants produce prodigious amounts of pollen. A single plant can produce 1 million to several million pollen grains in a day. In general, brightly colored flowering plants are of little clinical importance in inhalant allergy because their pollen is designed to be carried by insects (entomophilous) rather than by the wind (anemophilous). Many grasses, trees and weeds produce sufficient quantities of light-weight pollen to sensitize genetically susceptible individuals. The pollinating season of the various plants depends on the individual species and on the geographical location. However, for any particular plant in a given locale, the pollinating season is constant from year to year. Weather conditions, such as temperature and rainfall, influence the amount of pollen produced, but not the onset and termination of the pollen season. Pollen sampling and morphological identification can be routinely performed to determine the plant source and allergen load. Diagnosis of seasonal rhinitis is partly dependent on the correlation between the onset of symptoms and plant pollination time. Approx 60-75% of seasonal rhinitis patients have positive skin test reactions to weed pollens, 40% to grass pollens, and 10% to tree pollens.

Common plants causing allergy in humans are presented in Table 1. The listing is abbreviated and the reader should consult the tables in the article by Morrow and Slater in this volume for a more extensive listing of allergenic plants. The general category of "weeds" is used to group those invasive, undesirable plants that are not trees or grasses.

\*Author to whom all correspondence and reprint requests should be addressed.

**Table 1**  
**Common Allergenic Plants**

Family	Genus and species	Common name
Poaceae	<i>Cynodon dactylon</i>	Bermuda grass
	<i>Paspalum notatum</i>	Bahia grass
	<i>Sorghum halepense</i>	Johnson grass
	<i>Dactylis glomerata</i>	Orchard grass
	<i>Festuca pratensis (elatior)</i>	Meadow fescue
	<i>Lolium perenne</i>	Perennial rye
	<i>Poa pratensis</i>	Kentucky bluegrass
	<i>Agrostis gigantea (alba)</i>	Redtop, bent grass
	<i>Anthoxanthum odoratum</i>	Sweet vernal
	<i>Phleum pratense</i>	Timothy grass
Amaranthaceae (incl. Chenopodiaceae)	<i>Amaranthus</i>	Pigweed
	<i>Atriplex</i>	Scale
	<i>Chenopodium</i>	Lamb's quarter
	<i>Kochia</i>	Burning bush
	<i>Salsola</i>	Russian thistle
Asteraceae	<i>Ambrosia</i>	Ragweed
	<i>Iva</i>	Marsh elder
	<i>Artemisia</i>	Sage, mugwort
	<i>Xanthium</i>	Cocklebur
	<i>Baccharis</i>	Groundsel-tree
Polygonaceae	<i>Rumex</i>	Dock, sorrel
Plantaginaceae	<i>Plantago</i>	English plantain
Urticaceae	<i>Urtica</i>	Nettle
	<i>Parietaria</i>	Pellitory
Aceraceae	<i>Acer</i>	Maple
Betulaceae	<i>Betula</i>	Birch
	<i>Alnus</i>	Alder
	<i>Corylus</i>	Hazelnut
Cupressaceae	<i>Cupressus</i>	Cypress
	<i>Juniperus</i>	Junipers and cedars
	<i>Taxodium</i>	Bald-cypress
Fabaceae	<i>Acacia</i>	Acacia
	<i>Prosopis</i>	Mesquite
Fagaceae	<i>Quercus</i>	Oak
	<i>Fagus</i>	Beech
Hamamelidaceae	<i>Liquidambar</i>	Sweet gum
Juglandaceae	<i>Juglans</i>	Walnut
	<i>Carya</i>	Hickory and Pecan
Moraceae	<i>Morus</i>	Mulberry
Myricaceae	<i>Myrica</i>	Bayberry

**Table 1 (cont.)**

Family	Genus and species	Common name
Oleaceae	<i>Olea</i>	Olive
	<i>Fraxinus</i>	Ash
	<i>Ligustrum</i>	Privet
Platanaceae	<i>Platanus</i>	Sycamore
Salicaceae	<i>Salix</i>	Willow
	<i>Populus</i>	Cottonwood
Ulmaceae	<i>Ulmus</i>	Elm

The Asteraceae, Amaranthaceae, Urticaceae, Plantaginaceae, and Polygonaceae represent those weed pollens implicated in pollen allergy. Allergenicity important trees are represented by a more diverse taxonomic group including as many as 10 families. The trees are in general more geographically restricted than grasses and weeds and many species have been introduced.

### **The Grasses**

The grasses belong to the family Poaceae (Gramineae) with more than 600 genera and 10,000 species. Over 95% of the allergenically important grass species belong to the three subfamilies Pooideae, Chloridoideae, and Panicoideae. Grasses occur on all continents. The temperate zones are dominated by grasses belonging to the subfamily Pooideae. They account for approx 70–85% of the grasses in Canada and the northwestern US, 40–50% in the middle latitudes, and less than 15–25% in the southern US. The cool-season turf-grasses, bluegrass (*Poa*), bentgrass (*Agrostis*), fescues (*Festuca*), and ryegrass (*Lolium*) represent the major allergenic genera along with orchard grass (*Dactylis glomerata*), timothy (*Phleum pratense*) and vernal grass (*Anthoxanthum odoratum*), which are common in meadows, pastures, and waste places. This subfamily also includes the important cereals wheat (*Triticum*), rye (*Secale*), and barley (*Hordeum*).

Over 50% of the grass species in the southwestern US belong to the subfamily Chloridoideae, whereas they comprise less than 10% of the total in the northwestern US. The popular southern turfgrass, Bermuda grass (*Cynodon dactylon*) is widespread throughout the warmer regions of the world and is a major allergenic species.

The Panicoideae are common in the humid tropical to subtropical environments. Approximately 50% of the grasses in the southern US are panicoids, but only about 5% of the species belong to this subfamily in the northwestern US. Allergenicity important species include Bahia

grass (*Paspalum notatum*), an important forage and erosion-control grass in the Gulf Coast states, and Johnson grass (*Sorghum halepense*), a forage grass and frequently a troublesome weed in the warmer and tropical regions of both hemispheres. The cultivated sugar cane (*Saccharum officinarum*) and sorghum (*Sorghum bicolor (vulgare)*) belong to this subfamily.

### **The Conifers**

The conifers, which include the pine and cypress families, are found from the Arctic to the Southern Hemisphere. Pines are monoecious and their pollen grains are 50–100  $\mu$  in diameter and have two bladders. Owing to their pollen size and weight, the pines are only occasionally implicated in allergy.

The Cupressaceae (incl. Taxodiaceae) is a diverse family representing about 30 genera and comprising both large and small trees and shrubs. They are mainly dioecious and produce large quantities of pollen grains 25–35  $\mu$  in diameter. The female cones of junipers turn into fleshy berries, which distinguishes this family from most the conifers. Pollens from two genera, *Cupressus* and *Juniperus*, are allergenically important in the United States. The Arizona cypress (*C. arizonica*), as its name implies, is a western species as are the western junipers (*J. monosperma*, *J. pinchotii*, *J. scopulorum*, *J. osteosperma*, and *J. occidentalis*). These species survive in arid and alkaline soils and can be the only tree or shrub found in some habitats. *J. ashei (sabinoidea)* or mountain cedar, has been identified as an important cause of allergic rhinitis in certain regions of Texas. Its unique pollination season in these regions makes mountain cedar allergy an ideal model for investigating therapeutic approaches for allergic rhinitis. Occurring throughout the east is the species *J. virginiana*, commonly called the eastern red cedar or Virginia juniper. The bald cypress (*Taxodium distichum*) is an important timber tree of the coastal swamps in the southeastern US. In Japan, *Cryptomeria japonica* is considered an important cause of allergic rhinitis.

### **Hamamelidaceae: Witch Hazels and Sweetgums**

The Hamamelidaceae comprises 24 genera of trees and shrubs in the subtropic and warm-temperate regions of the world. Most species are in Asia and only the sweetgum (*Liquidambar styraciflua*) is both common and of allergenic importance in North America. Sweetgum grows from Connecticut southward throughout the East to central Florida and eastern Texas. It is found as far west as Missouri, Arkansas, and Oklahoma and north to southern Illinois. It also grows in scattered locations in northwestern and central Mexico, Guatemala, Belize, Salvador, Honduras, and Nicaragua. *L. styraciflua* may grow to 125 feet in height and 20 feet in circumference on a variety of sites (mainly bot-

tomlands) on the piedmont and coastal plains, and commonly reproduces vegetatively by root suckering. The leaves resemble that of the maple, and their flowers are inconspicuous and anemophilous.

### ***Platanaceae: Planes***

Two major species occur in North America: The eastern sycamore (*P. occidentalis*) and western or California sycamore (*P. racemosa*). The eastern sycamore occurs in mixture with sweetgum, box elder, maple, cottonwood, and willows, especially on frequently disturbed river bottoms. It remains abundant along the Mississippi river bottoms untouched by agricultural activities. The London plane (*P. x acerifolia*), a cross between the oriental plane (*P. orientalis*), native to Turkey and Greece and the American sycamore, is widely planted in European cities. The sycamore flowers appear in May in the northern parts of its range, and as early as late March in the South.

### ***Ulmaceae: The Elms***

There are about 10 species of elm trees in North America occurring east of the Rocky Mountains and represented by the American elm (*U. americana*) and hackberry (*Celtis occidentalis*). There are no native elms west of the Rockies, although the Siberian (*U. pumila*) and Chinese elm (*U. parvifolia*) have been introduced. Elm pollen is 35–40  $\mu$  in diameter, has five pores, and has a thick rippled exine. The American elm produces large quantities of pollen and is a major cause of allergy despite its destruction by Dutch elm disease. It is still abundant in Mississippi and Ohio River Valleys and their tributaries. American elm is common on wet flats and bottomlands but is not restricted to these sites.

### ***Betulaceae: The Birches***

This family is part of the evolutionary group that includes the witch hazels, elms, beeches and oaks. The family includes the birches, alders, hornbeams, and hazels. The 120 species of this family are found throughout the temperate, boreal, and arctic zones of the Northern Hemisphere. The birches are important causes of allergy in regions where they grow abundantly. They are monoecious and the male catkins open in the spring, releasing large quantities of pollen grains. *Betula occidentalis* (*fontinalis*) is a common, streamside shrubby birch throughout much of the Rocky Mountains, extending eastward into northwestern Ontario. Sweet/Black birch (*B. lenta*) occurs in cove sites along with hardwoods and white pine in the East. Its range extends from Maine to Alabama along the Appalachians. The river birch (*B. nigra*) is a large and common floodplain tree and occurs along creekbeds of the eastern deciduous forests alongside *Acer saccharinum*, *A. negundo*,

*B. occidentalis* and *Ulmus americana*. The white or gray birch (*B. populifolia*) is a successional tree on burned or cleared sites in the Northeast and is closely related to the European white birch (*B. pendula*). Tag alder (*Alnus rugosa*) forms swamp thickets, and the red alder (*A. rubra*) attains heights of over 100 feet and is an important hardwood tree in the Pacific northwest. It forms pure stands following fire or destructive logging and can be found in mixture with coastal conifers. Its range extends from the southern Yukon to southern California, in a narrow band within 100 miles of the Pacific coast. The American hazel (*C. americana*) is an abundant shrub throughout the eastern US and can occur as dense stands in wet sites.

### ***Fagaceae: The Oaks and Beeches***

The oak family contains five genera found in North America, of which only the beeches (*Fagus*) and the oaks (*Quercus*) are anemophilous and of allergenic importance. The American beech (*F. grandifolia*) ranges from Nova Scotia to Florida and westward to Missouri and Texas but is of only minor allergenic importance. In contrast, the oaks shed enormous amounts of pollen and are one of the most important aeroallergens where they are found in abundance. The genus *Quercus* is highly diverse owing to its variability and tendency to form natural hybrids. The oaks are native to all of the 48 contiguous states with the exception of Idaho. In order to simplify this taxonomic group, the oaks can be divided into two groups: the white and red (or black) oaks, with the following distinctive characteristics.

The red oaks have leaves with bristle-tipped teeth or lobes, or if entire-margined, then have a distinct bristle at the tips. The acorns do not mature until the second growing season; the inner surfaces of the shells are usually coated with woolly hair, and the kernels are usually bitter. The bark is typically dark-colored and furrowed. The white oaks, in contrast, have leaves with rounded teeth or lobes, but rarely bristle-tipped. The acorns mature in one growing season; the inner surfaces of the shells are smooth, and the kernels sweet. The bark is typically grayish and usually scaly. The red oaks are represented by *Q. velutina* and *Q. rubra*, the black and red oak, respectively. *Q. velutina* and *Q. rubra* are widely distributed throughout the eastern and central United States and extreme southwestern Ontario, Canada. In the United States, black oak occurs from southwestern Maine west to southern Wisconsin and southeastern Minnesota, south through Iowa to eastern Nebraska, eastern Kansas, central Oklahoma, and eastern Texas, and east to northwestern Florida and Georgia. The California black oak (*Q. kelloggii*) is distributed along foothills and lower mountains of California and southern Oregon. The California "live" oak (*Q. agrifolia*), abundant in the coastal regions of California, is a red oak.

The white oak (*Q. alba*) is one of our largest and most valuable forest trees, ranging throughout the eastern United States from southwest Maine to northern Florida, Alabama, and Georgia. It extends westward throughout southern Ontario and Quebec into central Michigan, northern Wisconsin, and southeastern Minnesota and south to southwestern Iowa, eastern Kansas, Oklahoma, and Texas. The best growing conditions for white oak occur on the western slope of the Appalachian Mountains and in the Ohio Valley and central Mississippi Valley. The typical "live" oak (*Q. virginiana*), occurring on the lower Coastal Plain of the southeastern United States from southeast Virginia to Florida, including the Florida Keys, and westward to southeast Texas, is a white oak. Bur oak is widely distributed throughout much of the north-central United States and the eastern Great Plains.

### ***Moraceae: The Mulberries***

The mulberry family comprises some 70 genera and 1400 species of mostly tropical to subtropical trees and shrubs. Some members of this family are entomophilous, but pollen from the mulberries (*Morus*) is regularly trapped in air samplers. The white mulberry (*M. alba*) was introduced from China as part the attempt to establish a silk industry in the US. The white mulberry is the only suitable food for silkworms (*Bombyx mori*). Today, it is mainly a "weedy" species of urban environments. The red mulberry (*M. rubra*) of the eastern US may grow to 60 feet or more and occurs in bottomlands, including coves and lower slopes, on a wide range of soil types. The paper mulberry (*Broussonetia papyrifera*) is still a source of high-quality paper used for lens paper and cosmetic tissues. The ornamental tree of the central US, osage orange (*Maclura*), and the fig (*Ficus*) belong to the same family, but are entomophilous and thus not important aeroallergens.

### ***Juglandaceae: The Walnuts and Hickories***

Of the 15 species of *Juglans*, three are commonly found in North America. The largest orchards of English walnuts (*J. regia*) are in California (over 125,000 acres). The California black walnut (*J. californica*) occurs at Walnut Creek and in the coastal ranges of southern California, in the hills of Los Angeles and Santa Monica. They produce pollen in abundance during April and May, but it is not carried far from the trees. The black walnut (*J. nigra*) is a valuable timber tree in the eastern US. In the northeastern United States, its pollen is conspicuous on pollen slides during May and the beginning of June. *Carya*, or the hickories, having 12 species in eastern North America, mostly produce small, hard nuts. The notable exception is the pecan (*C. illinoensis*) from the southern US, growing principally in the bottomlands of the Mississippi

River valley. Shagbark hickory (*C. ovata*) occurs throughout most of the eastern North America but is largely absent from the southeastern and Gulf coastal plains and the lower Mississippi Delta. These trees produce large amounts of highly allergenic pollen, which is 40–50  $\mu$  in diameter and contain three or four germinal pores with short elliptical or nearly circular apertures.

### ***Myricaceae: Bayberry***

North American species include bayberry, the source of myrtle wax (*Myrica cerifera*) and *M. californica* which is distributed from Washington to California. The diminutive flowers are unisexual, dioecious, and borne on catkin-like axillary spikes. The pollens resemble that of the birches and are anemophilous. *Myrica cerifera* grows in thickets near swamps and marshes and is common in a variety of habitats and plant communities in the southeastern United States. It grows equally well with the subtropical vegetation of south Florida and is planted as an ornamental on a variety of sites, but seems to be restricted to climates with mild winters and long, hot, humid summers, and elevations below 500 feet (150 m).

### ***Aceraceae: The Maples***

Over 15 species of maple are found in North America and many are significance sources of aeroallergens. The most widely distributed species, *Acer negundo*, or box elder, is a prolific producer of pollen and thus one of the most allergenically important maples. Box elder is widespread in riparian and palustrine communities throughout most of the contiguous United States and flowers from March through May with or before the appearance of the leaves. The red (*A. rubrum*), silver (*A. saccharinum*), and sugar (*A. saccharum*) maples are widely distributed in eastern North America. The sugar maple, as with box elder, produces an abundance of pollen and is also considered to be an important allergen source. The maples are one of the first trees to flower in early spring. Specific flowering dates are largely dependent on weather conditions, and latitude and elevation.

### ***Oleaceae: The Olives, Ashes, and Privet***

The olive family comprises about 20 genera of trees and shrubs, most of which are entomophilous and of limited importance. The exceptions are *Olea*, *Ligustrum*, and *Fraxinus*. The pollens grains, 20–25  $\mu$  in diameter with a coarsely reticulate exine, are flattened and have three to five furrows. Of the more than 60 species of *Fraxinus*, *F. pennsylvanica* or green ash is the most widely distributed. Its range extends from Cape Breton Island and Nova Scotia to southeastern Alberta and Montana, and southward to central Texas and northern Florida. White ash

(*F. americana*) is found mainly in eastern North America. It occurs from Nova Scotia west to eastern Minnesota and south to Texas and northern Florida. The majority of ashes in the United States are entirely anemophilous and their pollen is among the most abundant identified in pollen slides during the early spring season. *O. europaea* is a small spreading tree, primarily insect-pollinated, but is known to produce large amounts of pollen that become airborne. It can be an important cause of pollinosis in California, Arizona, and in the Mediterranean areas, where they are extensively grown for their fruit. The privets are primarily evergreen shrubs bearing small white fragrant flowers. The common privet (*Ligustrum vulgare*) is grown as a hedge plant because it tolerates shearing and grows 12–15 feet high and spreads 12–15 feet. It is primarily entomophilous but its pollen, similar in morphology to the other members of the family, do become airborne when the plants are shaken.

### ***Salicaceae: The Willows and Poplars***

The willows (*Salix*) are insect-pollinated and are not considered important aeroallergen sources. The poplars (*Populus*) are dioecious, wind-pollinated and produce spherical pollen grains, and are 25–35  $\mu$  in diameter, with thick intines and thin exines. Eastern cottonwood (*P. deltoides*) is the fastest growing native tree in North America. It commonly increases 5 feet in height each year for the first 10–15 yr and grows at only a slightly slower rate up to 30–35 yr of age. Eastern cottonwood occurs from southern Quebec and Ontario south to Florida. It extends west to North Dakota and through the eastern parts of Nebraska, Kansas, Oklahoma, and Texas. Plains cottonwood is found through the Great Plains region to the foothills of the Rocky Mountains, northeastern New Mexico, and northern Texas. Rio Grande cottonwood (*P. wislizenii*) occurs along the Colorado River from southern Colorado to southeastern Utah and northeastern Arizona, extending to the Rio Grande drainage in western Texas, New Mexico, and northwestern Mexico. Where the western limit of eastern cottonwood and the eastern limit of plains cottonwood overlap, plants display intermediate morphological characteristics. Fremont cottonwood occurs in riparian habitats from western Texas west through New Mexico, Arizona, and California, and northward into Nevada, Utah, and Colorado.

### ***Fabaceae (Including Mimosaceae)***

The mimosa, acacias, locusts, and mesquites are leguminous plants and can be grouped to form the plant family *Fabaceae* (*leguminosae*), which contains just under a twelfth of the world's flowering plants. Many species are important as crop plants (e.g., soybeans and peanuts) and their pollens are not allergenically important. They are responsible

for much of the world's soil fertility through nitrogen fixation. Among the genera that are potentially important in pollinosis are *Acacia*, *Robinia*, *Prosopis*, and *Mimosa*. The acacias are primarily tropical and subtropical trees, found in the hot and arid regions of America, and are cultivated as ornamental trees. The common name acacia is also applied to *Robinia pseudoacacia* or the black locust, ranging in the central Appalachian Mountains from central Pennsylvania and southern Ohio to northern Alabama, Georgia, and South Carolina. The locust tree has been successfully planted in every state. The mesquites (*Prosopis*) occurs throughout most of Texas, southern New Mexico, Arizona, Colorado, and Kansas. Mesquites hybridize naturally and thus many intermediate forms exist, making identification difficult at the species level.

### ***The Amaranthaceae (Including Chenopodiaceae): Pigweeds and Chenopods***

The Amaranthaceae and Chenopodiaceae are closely related although not generally similar in appearance. Their pollen grains are similar being spheroidal 20–35  $\mu$  in diameter with a thin and granular exine. The genus *Amaranthus* is represented by the ubiquitous *A. retroflexus*, or redroot pigweed, found in cultivated or waste soil throughout North America. It is also found throughout much of the rest of the world, including Europe, South America, Eurasia, and Africa. It is a native of tropical America. *A. palmeri* (carelessweed) is distinguished by its long slender terminal flowering spikes, shedding much more pollen than other species of this genus. This species is abundant in Missouri, Kansas, Oklahoma, and eastern Texas. The western waterhemp (*A. tuberculatus*) is abundant in the prairie region from South Dakota, Nebraska, Kansas, and south through eastern Texas and Oklahoma, where it is most abundant.

The chenopods comprise about 75 genera of world-wide distribution and are represented by the summer blooming *C. album* (lamb's quarter), introduced from Europe and naturalized throughout North America. *C. ambrosioides* (Mexican tea) was introduced from tropical America and is also naturalized throughout North America and flowers from August to October. *C. botrys* (Jerusalem oak) is occasionally cultivated in the northern United States and Canada, and flowers from July to September. Russian thistle (*Salsola pestifer*), commonly known as "tumbleweed," ranges throughout the prairies, much of the Rocky Mountains, and the Great basin area. It flowers from June to September and is probably the most important cause of hay fever among the chenopods. *Kochia* or firebush, named for its red leaves of autumn, was introduced from Europe and Asia primarily as a garden plant. It has escaped cultivation and is now naturalized throughout North America with the exception of the Southeast. Native to Eurasia, the Russian

thistle is distributed throughout most arid and semiarid regions of the world. In North America, Russian thistle is most common in central and western regions of Canada and the United States, and along the Atlantic and Gulf coasts.

The saltbushes (*Atriplex*) are primarily found in the western United States and shed large amounts of pollen. *A. canescens* (wingscale) is by far the most widely distributed of the genus, ranging from Alberta to Kansas, western Texas, Mexico, Baja California, Washington, and Montana.

### ***The Asteraceae: Sunflower Family***

Also known as the Compositae, this family of 13,000 species in 900 genera forms one of the largest of flowering plant families. They are mainly herbaceous plants distributed over most of the world and grown for their attractive flowers. The most important among the anemophilous species are the ragweeds, sagebrushes, mugworts, and wormwoods of the genus *Ambrosia* and *Artemisia*.

#### *Ragweeds*

The ragweeds are some of the most important allergenic weeds in North America. The giant ragweed (*Ambrosia trifida*) can reach a height of 15 feet. Short ragweed (*A. artemisiifolia*) and other species of ragweed (*A. bidentata*, *A. psilostachya*) grow to about 4 feet in height and shed enormous amounts of pollen. The ragweeds are highly invasive pioneer plants. Introduced from North America, the ragweeds have invaded Hawaii, Europe, and Japan. The plants are limited in their distribution by length of day and temperature; they flower only under short day conditions of 12 hr or less of sunlight. They are, thus, found in great abundance between latitudes 45° and 30°.

*Artemisia tridentata* or common sagebrush is one of the most widespread and economically important shrubs in western North America. It is most prevalent in the Great Basin and Northwest. California sagebrush is endemic to California. Various times of flowering have been reported, including periods from August through December, and year-round. *A. vulgaris*, or common mugwort, is found mainly on the East Coast and Midwest. The pollen grains of sagebrush and mugwort are indistinguishable, being 20–30  $\mu$  in diameter, with three furrows, central pores, and a thick exine with no spines. The pollen allergens of the two species are highly cross-reactive.

#### *Cocklebur*

The cocklebur (*Xanthium*) and marshelders (*Iva*) can also be major causes of pollinosis. The pollen grains, ranging from 20–30  $\mu$  in diameter, are difficult to distinguish. Common cocklebur (*X. strumarium*

(*commune*) has a nearly worldwide distribution. In North America it is widespread across southern Canada, most of the contiguous United States with the exception of northeastern New York and Maine and in mountainous terrain. It grows in cultivated fields, in waste areas, and on beaches and sand dunes. The plant will not flower at all or only poorly when day length exceeds 14 hr. Thus, flowering does not occur until late summer in most regions.

### *Baccharis*

*Baccharis*, or groundsel-tree, grows along the Atlantic and Gulf coasts of North America from Mexico, through Texas, and peninsular Florida to Massachusetts. *B. halimifolia* is most common on the southeastern Coastal Plain, growing as far inland as Arkansas and the central Piedmont Plateau. It grows in moist sites with a high organic content including pond and bay margins, swamps, wet prairies, marshes, and everglades hammocks. It pollinates from August to October and have been reported to be important as a hay-fever plant in parts of Florida. In the western states, *Baccharis* spp., commonly named mulefat and desert broom, are found in moist, sunny streambeds, ditches, and desert oases. *B. sarothroides* is a prolific producer of pollen and has been identified as an important aeroallergen in Arizona and New Mexico.

### ***Urticaceae: The Nettle***

In North America, this family is best known for the stinging nettle (*Urtica*), which is the most common genus in temperate North America and occurs throughout Canada and much of the United States. In the East and Midwest, *U. dioica* occurs as far south as Virginia, Missouri, and Kansas; in the West, it occurs south along the coast to central California and south in the Rocky Mountains to Mexico. Stinging nettle is characterized by leaves, stems, and flowers that are sparsely to moderately covered with stinging hairs. It occurs in moist sites along streams, coulees, and ditches, on mountain slopes, in woodland clearings, and in disturbed areas. *U. dioica* flowers from late May to October. In northern areas, flowering is condensed into a shorter time period, ending in late August. In the Mediterranean regions of Europe, the family is best known for the wall pellitory (*Parietaria*), a plant similar to the nettles but lacking hairs that sting. Its thin-walled and nearly smooth pollen, 12–16  $\mu$  in diameter and with 3 or 4 pores, are nearly indistinguishable from nettle pollen. Three or four species of *Parietaria* are established in some regions of the United States, but they have not yet been established as important aeroallergens.

### ***Plantaginaceae: The Plantains***

*Plantago lanceolata*, or English plantain, is the only allergenic member of this family. It pollinates during the grass pollen season (May–June) and its pollen can be distinguished by the multiple scattered pores and variable size (20–40  $\mu$ ). It is an acaulescent perennial with flowers in a terminal spike. Flowering progresses from the base to the tip of the spike over a period of weeks.

### ***Polygonaceae: The Docks***

The Polygonaceae, or the buckwheat family, is a diverse group of about 40 genera including herbs, shrubs, and a few trees characterized by their swollen nodes and with a membranous collar or sheath (ocrea). All of the members of the family are entomophilous with the exception of the rhubarb (*Rheum rhaponticum*) and the docks (*Rumex*). The rhubarb has long been cultivated for culinary use in pies and desserts but there are no reports of rhubarb pollen as a cause of pollinosis. The genus *Rumex* is the only known allergenic member of this family. *R. acetosella* (sheep sorrel) and *R. crispus* (dock) are the most important species. *R. acetosella*, found throughout North America, sheds its pollen during the summer months (May–June) and is a common weed in dry, acidic fields. *R. crispus* is similar in appearance to *R. acetosella* but is taller with broader, curly leaves. The two species are known to hybridize naturally.

### ***Plants of Regional or Limited Allergenic Importance***

Australian pine was introduced to the United States near the turn of the century from Australia, the Phillipines and Pacific islands. *C. equisetifolia*, a medium to tall evergreen tree resembling true pine in appearance, is the most common species planted in southern Florida as a wind-break and is also found in California, Arizona, and Hawaii. It is anemophilous and sheds large amounts of pollen in late summer, although they can flower year-round. Australian pine can colonize nutrient-poor soils. It can grow in sloughs, glades, wet prairies, along rocky coasts, sandbars, dunes, and in water-logged clay or brackish tidal areas.

Russian-olive (*Elaeagnus*), a native of Eurasia, was introduced into the United States in the early 1900s and now is now extensively naturalized in the western states bordered on the east by the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. It is fast-growing, drought-tolerant, and makes an excellent windbreak. It grows in some eastern states but is not naturalized. It is commonly found growing along floodplains, riverbanks, stream courses, marshes, and irrigation ditches. Twigs are often spiny with a scale-like covering and the fruit is about 1/2", elliptical, drupe-like, and yellow-pinkish with a silvery

scale-like covering. In the western states, the Russian olive, along with tamarisk (saltcedar), has become a major problem in riparian woodlands, threatening even large, hardy native trees such as cottonwood. *E. umbellata*, a closely related species and also invasive, is found from Maine south to Virginia and western North Carolina, and west to Wisconsin.

Saltcedar, or tamarisk (*Tamarix gallion*) gellicat, is an invasive exotic plant species that is well established in the southwestern United States, particularly in riparian areas. The species has the dubious distinction of being included on the California Exotic Pest Plant Council's list of exotic pest plants of greatest ecological concern. The rapid spread of saltcedar throughout the southwestern United States has been partly owing to the damming of rivers for flood control, which created conditions favoring saltcedar over the native species.

Brazilian pepper (*Schinus terebinthifolius*) is indigenous to the coast of tropical Brazil. In the continental United States, Brazilian pepper is naturalized on a significant scale only in southern Florida, ranging from mangroves to pinelands. Brazilian pepper has also been introduced in Hawaii, California, and Texas. It grows best on well-drained wastelands and abandoned oilfields. Brazilian pepper flowers in October to January and is pollinated by a native syrphid fly.

### Fungi (5–8)

The role of fungi in respiratory allergy is well established but the major clinical problem has been to establish the extent to which a particular patient's symptoms can be attributed to fungi. A wide variety of fungi can be isolated from the indoor and outdoor environments throughout the year. This is in contrast to pollen and animal-dander allergens, which have distinct seasons or a defined history of exposure and symptoms. Respiratory problems induced by certain activities such as grass mowing and gardening may be helpful in identifying mold-sensitive subjects. Approximately 20–30% of atopic individuals are sensitized to one or more fungal allergens based on skin tests or in vitro assays. The 10 most common allergenic fungi are *Alternaria*, *Bipolaris* (*Helminthosporium*), *Cladosporium*, *Aspergillus*, *Penicillium*, *Epicoecum*, *Fusarium*, *Stemphylium*, *Botrytis*, and *Curvularia* based on prevalence and on skin sensitization among allergic patients. The true prevalence of sensitization to specific fungi is difficult to establish because there are no standardized allergen preparations for diagnostic use and many allergenically important species are not commercially available.

Because of their unique structure and physiology, most biologists separate the Kingdom Plantae from the Kingdom Fungi. The fungi are plant-like eukaryotes that form spores and lack chlorophyll.

### ***Phylum Zygomycota***

The zygomycetes are saprophytic or parasitic fungi that reproduce asexually by the formation of sporangia or conidia and sexually by the formation of zygospores. Their hyphae lack cross walls or septa. Inside the sporangia, which can be nearly 0.5 mm in diameter, are the sporangiospores. The zygospore is formed by conjugating hyphae from two distinct and compatible mycelia. Cytoplasm and nuclei flow to the contacting tips of the zygospore and form diploid nuclei. In some species, the spores form a dry, powdery mass that are easily dispersed into the air. A number of zygomycetes are coprophilous, growing only on the dung of certain animals. Of the three classes of zygomycetes, only the Mucorales (*Mucor* and *Rhizopus*) are known to be allergenic.

### ***Phylum Ascomycota***

The ascomycetes are a large, diverse, economically important group with tens of thousands of species. The formation of ascospores characterizes this phylum. Ascospores are borne in an ascus, or a capsule formed when compatible hyphae mate. In the ascus, the respective nuclei fuse and after the appropriate number of meiotic and mitotic divisions, the ascospores that form are released. Asexual reproduction is by budding or the formation of conidia. Some ascomycetes occur in marine habitats and may be saprophytic or parasitic on marine algae. Many species are destructive to timber and ornamental trees and cause plant diseases such as apple scab, ear rot of corn, and powdery mildews. The ascomycete *Chryphonectria parasitica* completely annihilated the chestnut forests of America and another ascomycete, *Ophiostoma ulmi*, threatens the American elm with extinction. The Class Hemiascomyceteae, represented by the yeasts, generally do not grow hyphae. *Saccharomyces cerevisiae*, known as brewer's or baker's yeast, has been cultivated for thousands of years. The Class Euascomyceteae is the largest and most diverse class, represented by morels, truffles, and the most fungal partners in lichens. *Neurospora*, a common laboratory organism useful in genetic research, is a euascomycete. Of this rather large group of fungi, only *S. cerevisiae* and *Chaetomium* spp. have been implicated in allergy. On the other hand, if we include all the Deuteromycetes with euascomycetous forms (*Aspergillus*, *Penicillium*, *Fusarium*, *Epicoccum*, *Alternaria*, *Cladosporium*, *Trichoderma*, *Phoma*, and *Botrytis*) this class gains enormous allergenic importance.

### ***Phylum Basidiomycotina***

The basidiomycetes include the mushrooms, puffballs, smuts, and rusts. Like ascomycetes, to which they are related, basidiomycetes possess hyphae with septa and lack motile spores. Asexual spores, when formed, are produced as conidia. There are two classes of basidiomycetes, the Heterobasidiomycetae (rusts and smuts) and the Homobasidiomycetae (mushrooms and puffballs). The rust fungi (*Puccinia*) cause diseases of many cereal crops and have complex life cycles that are dependent on seasonal conditions as well as the biology of their host plants. Until recently, only the smuts, rusts, and *Merulius lacrymans* had received attention as being allergenically important. This has been in part owing to the difficulty in differentiating and identifying basidiospores in aeroallergen samples. Improved aeroallergen sampling and immunochemical methods, however, have identified additional members of the phylum as allergenic.

### ***Deuteromycota***

The deuteromycetes, or Fungi Imperfecti, are a grouping of fungi lacking a complete set of sexual reproductive structures. Most if not all deuteromycetes are thought to be ascomycetes or basidiomycetes that have lost their ability to generate ascospores or basidiospores. Indeed, the sexual structures of many fungi previously classified as imperfect have been (re)discovered. There are over 20,000 species of deuteromycetes, including many that are allergenically important. The group can be divided into at least three form classes. The Sphaeropsidaceae, represented by *Phoma*, reproduce by the forming of flask-shaped bodies called pycnidia. These structures resemble the perithecia of ascomycetes, the difference being that pycnidia contain conidia and perithecia contain asci. The Moniliaceae includes all imperfect fungi, which produce conidia on unorganized hyaline (colorless) conidiophores or directly on hyaline hyphae. The anamorphic *Aspergillus*, *Penicillium*, *Botrytis*, and *Fusarium* belong in this class along with the dermatophytes, *Trichophyton*, *Epidermophyton*, and *Microsporum*. The Dematiaceae possess hyphae and conidia that are typically dark as opposed to hyaline and are considered the most important from the standpoint of allergy to fungi. *Alternaria*, *Cladosporium* (*Hormodendrum*), *Bipolaris* (*Helminthosporium*), *Stemphylium*, *Curvularia*, and *Epicoccum* are some of the most commonly encountered dematiaceous moulds.

### ***Ecology of Fungal Growth***

The term “mould” is commonly used to refer to the cottony growth on foods, plants, and other items encountered in our home or work environment. Yeasts are true fungi but lack hyphae and are not molds.

They form slimy colonies on enriched media and resemble bacteria. They are about 2–3  $\mu$  across and are about 10 times larger than the average bacterial cell. Actinomycetes are classified as bacteria even though they resemble molds. They grow as filaments of less than 1  $\mu$  in diameter. Mold spores usually germinate to grow slender microscopic filaments called hyphae typically surrounded by cell walls containing chitin, cellulose, or both. They resemble plants but do not possess stems, roots, or leaves. The hyphae elongate by apical growth and form a mass visible by the naked eye called the mycelium. Fungi may reproduce both asexually and sexually. Asexual sporulation results from simple division or modification of individual hyphae. Yeasts reproduce asexually by budding. Spores may occur in sporangia (sporangiospores) or they may be borne directly at the tips of hyphae (conidia). Sexually derived spores are sometimes difficult to identify and one must learn to recognize certain indications of the sexual process. The four types of sexually derived spores are the oospores, zygosporangia, ascospores, and basidiospores. The reproductive structures exhibit a variety of forms and it is on this basis that we classify the fungi.

Fungi can withstand desiccation and other environmental stresses, in part because their cell walls are of chitin, a nitrogenous polysaccharide. They secrete a variety of enzymes directly into their environment to digest their food and absorb them. The fungi are responsible for much of the disintegration of organic matter and can increase the fertility of soil by releasing plant nutrients in a form available to green plants. They are the basis of a number of industrial processes involving fermentation, such as the making of bread, wine, cheese, and beer. On the other hand, they may destroy foodstuffs, damage crops by parasitizing plants, and cause diseases of animals and humans. Their digestive enzymes (especially proteases) may also induce unwanted degradation of allergens in allergy vaccines.

Airborne fungal spores can exceed that of pollen by a thousandfold depending upon meteorological conditions. Outdoor spore levels tend to be higher than those measured indoors, and the outdoor spore levels have a significant influence on indoor levels. Table 2 lists some of the important allergenic fungi, their prevalence, and their habitat.

### **Animals (9,10)**

A variety of domesticated animals live and work in close contact with humans as companions or livestock. Over 100 million domestic animals reside in the US; cats and dogs are the most common co-habitants and are found in more than one-third of all homes in the US. Occupational exposure to rodents (rats, mice, and guinea pigs) among laboratory animal technicians and to cows, horses, and pigs among

**Table 2**  
**Allergenic Fungi**

Fungi	Prevalence/habitat
<i>Alternaria alternata</i> ( <i>Alternaria tenuis</i> )	Cosmopolitan. Isolated from a variety of plants and from soil.
<i>Aspergillus amstelodami</i> ( <i>Aspergillus glaucus</i> )	Cosmopolitan. Isolated primarily from soil, plants, and house dust.
<i>Aspergillus flavus</i>	Cosmopolitan. Isolated mainly from plants and soil. Found on peanuts.
<i>Aspergillus fumigatus</i>	Ubiquitous. Peaks during high humidity and warm weather. Found often in humidifiers, dehumidifiers, basements, attics, plants, food.
<i>Aspergillus niger</i>	Ubiquitous. Common black bread mold. Isolated from soil and decomposing plant material.
<i>Aureobasidium pullulans</i> ( <i>Pullularia pullulans</i> )	Cosmopolitan. Found in bark of sequoia trees and on plant leaves.
<i>Bipolaris sorokiniana</i> ( <i>Helminthosporium sativum</i> )	Cosmopolitan. Isolated from soil and plants. Found more in the tropical and subtropical areas.
<i>Botrytis cinerea</i>	Cosmopolitan. Often found in regions of high humidity. Can be found indoors on decaying fruits and vegetable matter.
<i>Candida albicans</i>	Common. Normal flora on mucous membranes of warm-blooded animals.
<i>Chaetomium globosum</i>	Common. Isolated from soil and decomposing plant materials, especially straw, mulch, and from herbivore dung.
<i>Cladosporium herbarum</i>	Ubiquitous. Found frequently in air, soil, and plant debris.
<i>Cladosporium sphaerospermum</i> ( <i>Hormodendrum hordei</i> )	Ubiquitous. Found frequently in air, soil, and plant debris.
<i>Drechslera spicifera</i> ( <i>Curvularia spicifera</i> )	Cosmopolitan. Isolated from soil and plants. Found more in the tropical and subtropical areas.
<i>Epicoccum nigrum</i>	Cosmopolitan. Isolated from soil and plants.
<i>Fusarium moniliforme</i>	Cosmopolitan. Isolated from soil and plants.
<i>Mucor spp.</i>	Cosmopolitan. Isolated from soil and decaying organic material.
<i>Penicillium chrysogenum</i>	Ubiquitous. Found on food products, spores are often airborne.
<i>Penicillium digitatum</i>	Cosmopolitan. Found on citrus fruits.
<i>Penicillium notatum</i>	Ubiquitous. Found on citrus fruits and food products.
<i>Phoma betae</i>	Common. Parasitizes sugar beets.
<i>Puccinia graminis</i>	Common. Rusts. Produces rust-colored spores on the leaves and stems of the primary host (oats, wheat).

**Table 2 (cont.)**

Fungi	Prevalence/habitat
<i>Rhizopus stolonifer</i> ( <i>Rhizopus nigricans</i> )	Ubiquitous. Causes spoilage of refrigerated foods. Found on cereal grains.
<i>Saccharomyces cerevisiae</i>	Common. Common bread yeast (baker's and brewer's yeast).
<i>Stemphylium solani</i>	Common. Plant pathogen. Causes leaf spot on tomatoes.
<i>Trichophyton mentagrophytes</i> ( <i>Trichophyton interdigitale</i> )	Common. Causes athlete's foot and inflammatory skin lesions.
<i>Ustilago spp.</i>	Common. Smuts sp.= <i>cynodontis</i> (Bermuda grass); <i>maydis</i> (corn); <i>avenae</i> (oat); <i>tritici</i> (wheat).

farmers and veterinarians can result in sensitization and allergic symptoms. Animals raised for fur production (mink, fox, and raccoons) can also be an occupational risk for sensitization. Sensitization to one or more animal species may increase the risk for sensitization to other species. Avian allergens have been implicated in hypersensitivity pneumonitis as well as allergic rhinitis and asthma among bird-fanciers and breeders. Positive skin-test reactions to animal allergens occur at a rate of about 20–30% among the atopic population, but the relationship between sensitization as demonstrated by skin test reactivity and its clinical relevance is not known. One reason for this is the lack of well-characterized or standardized diagnostic allergen preparations. At this time, only products derived from cat source materials are standardized.

Strictly speaking, animals include a wide taxonomic grouping including invertebrates and vertebrates. Invertebrates, especially the arthropods (insects, mites, and crustaceans) and helminths, can be important sources of allergens, and are discussed in another section. Among the vertebrates, the most important animals causing allergy in humans are mammals. Birds can be sources of allergens causing bronchial asthma and allergic alveolitis (hypersensitivity pneumonitis). Fishes may be important causes of food allergies, but they are not major aeroallergen sources. Evidence of allergy to reptiles or amphibians is rare.

Mammals have a four-chambered heart and are homeothermic. The body is covered with an insulating layer of hair, and after birth, the young are nourished on milk secreted by the mammary glands of the mother. The hair, milk, and other secretions are important sources of mammalian allergens. Like mammals, birds are warm-blooded. All birds lay eggs and their bodies are covered with feathers. Avian allergens have been identified in feathers, epithelia, serum, and droppings.

**Table 3**  
**Common Allergenic Animals (Mammals and Birds)**

Class	Order	Family	Genus and species	Common name	
Mammalia	Marsupialia	Didelphiidae	<i>Didelphis marsupialis</i>	Opossum	
		Insectivora	Soricidae	<i>Sorex spp.</i>	Shrews
			Talpidae	<i>Scalopus aquaticus</i>	Eastern mole
	Perissodactyla	Equidae	<i>Equus caballus</i>	Horse	
		Artiodactyla	Bovidae	<i>Bos domesticus</i>	Cow
			Cervidae	<i>Ovis virginianus</i>	Sheep White-tailed deer
	Carnivora	Suidae		<i>Sus scrofa</i>	Pig
			Felidae	<i>Felis domesticus</i>	Cat
			Canidae	<i>Canis familiaris</i>	Dog
		Procyonidae		<i>Urocyon cinereoargenteus</i>	Gray fox
				<i>Procyon lotor</i>	Raccoon
			Mustelidae	<i>Mustela spp.</i>	Minks and Ferrets
	Rodentia	Muridae		<i>Mus musculus</i>	House
				<i>Rattus norvegicus</i>	Rat
				<i>Gerbillus campestris</i>	Gerbil
				<i>Cricetus cricetus</i>	Common hamster
		Caviidae	<i>Cavia porcellus</i>	Guinea pig	
Sciuridae		<i>Sciurus niger</i>	Eastern fox squirrel		
Aves	Lagomorpha	Leporidae	<i>Oryctolagus cuniculus</i>	Rabbit	
	Galliformes	Phasianidae	<i>Gallus domesticus</i>	Chicken	
		Meleagrididae	<i>Meleagris gallopavo</i>	Turkey	
	Columbiformes	Columbidae	<i>Columba livia</i>	Pigeon	
	Psittaciformes	Psittacidae	<i>Melopsittacus undulatus</i>	Parakeet (Budgerigar)	
			<i>Serinus canaria</i>	Common canary	

Table 3 lists the relationship among common animals that have been established or suspected as important allergen sources.

### **Furry Pets**

The domestic cat is the most common household pet in urban areas and based on a survey of about 16,000 individuals in the US, 2.3% had positive skin prick tests to cat-dander extracts. Based on this data, approx 6 million Americans could be allergic to cats. Several allergenic

source materials have been identified including hair or dander, pelt, saliva, and urine from male cats. More than 30% of American households have at one time or another owned a dog as a pet. Allergenic activity has been demonstrated in saliva and dander, but urine did not possess significant allergenic activity. There is conflicting evidence on the existence of breed-specific allergens. The industry practice is to include source materials from multiple breeds and mixed-breeds.

### ***Laboratory Animals***

Allergic symptoms are reported at a rate of 25–30% among laboratory animal workers exposed to mice, rats, guinea pigs, rabbits, hamsters, dogs, cats, and monkeys. Among those laboratory workers who are sensitized, the majority are sensitive to rats, mice, and rabbits, while 24–33% are sensitive to guinea pigs. The most important allergen source is the urine of rats, mice, and guinea pigs, and airborne dust particles have been shown to be carriers of urinary allergens. Rodent, especially rat and mouse, allergens have been most widely studied and characterized biochemically. Mouse urinary proteins have been detected in air samples from inner-city dwellings but their clinical significance is not yet known.

### ***Farm Animals***

Cow dander is an important cause of allergic sensitization among dairy farmers and veterinarians. The prevalence of sensitivity to cattle in the general or atopic population is not known. Horse allergens were studied extensively during the 1950s owing to the severe reactions experienced after injection of therapeutic horse serum in subjects sensitized to horse proteins. It is of interest to note that horse allergens have been detected in dust samples collected from homes.

### ***Birds***

Positive skin test reactions to a variety of bird feathers occur in about 20% of pigeon and canary fanciers with allergic rhinitis and asthma. It is estimated that there are more than 25 million birds in US households with canaries, parakeets, parrots, and cockatoos being most popular. Increasing numbers of exotic birds (e.g., Amazon blue-fronted parrots, African peach-faced lovebird, etc.) are being imported. The feathers, saliva, and lipoproteineous secretions derived from the uropygial or preen glands are potential sources of allergen. Avian allergens may become airborne on microscopic feather sheath fragments, powder-downs, and epithelial scales. Avian proteins can also cause hypersensitivity pneumonitis among 5–20% of bird fanciers and breeders. Serum proteins, especially immunoglobulins, and proteins found in pigeon bloom appear to be the major allergens in pigeon-breeder's

**Table 4**  
**Common Arthropod Allergens**

Class	Order	Family	Genus and species	Common name	
Crustacea	Decapoda	Portunidae	<i>Callinectes sapidus</i>	Crab	
		Homaridae	<i>Homarus americanus</i>	American lobster	
		Panaeidae	<i>Penaeus</i> spp.	Shrimp	
Arachnida	Acarina	Pyroglyphidae	<i>Dermatophagoides farinae</i>	House dust mite	
			<i>Dermatophagoides pteronyssinus</i>	European House dust mite	
		Tyroglyphidae	<i>Blomia tropicalis</i>	Tropical house dust mite	
Insecta	Ephemeroptera	Various	Various	Mayfly	
	Blattodea	Blattidae	<i>Periplaneta americana</i>	American cockroach	
			<i>Blatta orientalis</i>	Oriental cockroach	
		Blattellidae	<i>Blattella germanica</i>	German cockroach	
	Hemiptera	Reduviidae	<i>Triatoma</i> spp.	Kissing bug	
		Cimicidae	<i>Cimex lectularius</i>	Human bed bug	
	Lepidoptera	Various	Various	Moth	
	Trichoptera	Various	Various	Caddisfly	
	Coleoptera	Coccinellidae	Various	Ladybird beetle	
	Diptera	Ceratopogonidae	Various	<i>Culicoides</i> spp.	Biting midges, punkies
				Chironomidae	Various
		Culicidae	Various	<i>Culex</i> , <i>Aedes</i> , <i>Anopheles</i> , etc.)	Mosquito
				Simuliidae	<i>Simulium</i> , etc.
Tabanidae		<i>Tabanus</i> , <i>Hybomitra</i>	Horse fly		
	<i>Chrysops</i> spp.	Deer fly			
Hymenoptera	Apidae	<i>Apis mellifera</i> <i>Bombus</i> spp.	Honey bee Bumble bee		

**Table 4 (continued)**  
**Common Arthropod Allergens**

Class	Order	Family	Genus and species	Common name
		Formicidae	<i>Pogonomyrmex</i> <i>Solenopsis invicta</i>	Harvester ant Red imported fire ant
			<i>Solenopsis richteri</i>	Black imported fire ant
		Vespidae	<i>Polistes</i> spp. <i>Vespula</i> spp. <i>Dolichovespula</i> spp. <i>Vespa crabro</i>	Paper wasp Yellow jacket "Hornet" True hornet

disease. Diagnosis is based on clinical presentation and the presence of precipitating IgG antibodies toward these proteins.

### Arthropods (11–15)

The phylum Arthropoda comprises more than 80% of all known animals. Included in this phylum are insects, spiders, ticks, mites, crabs, lobsters, and shrimp (see Table 4). Medical interest in the arthropods is largely focused on their importance as carriers of viral, rickettsial, and parasitic diseases. Their importance in allergy is most commonly recognized in the anaphylactic reactions to the stings of bees, yellow jackets, hornets, wasps, and fire ants. Allergic reactions may also be produced by the salivary secretions of biting arthropods such as mosquitoes, flies, lice, fleas, and kissing bugs. The emanations and body parts of certain arthropods may become airborne and elicit respiratory symptoms in sensitized individuals. Gastro-intestinal symptoms may result from ingesting crustaceans such as crabs, shrimp, and lobsters. Other arthropods may be ingested as contaminants in foods. When considering insects as an outdoor allergen source, knowledge of the seasonal presence may be useful in controlling exposure. For example, certain aquatic insects (e.g., caddisfly, mayfly, and midges) emerge or swarm during specific months of the year. In contrast, other insects (e.g., the German cockroach) and mites (e.g., house-dust mite) are domestic and live almost exclusively indoors.

#### *The Stinging Insects*

There are several important groups of stinging insects found in North America, and all are social (meaning that they live in colonies) members of the order Hymenoptera, which includes wasps, bees, and

ants. In the case of social insects, the colonies may be either annual or perennial, depending on the type of insect. In all cases, only the female insects sting; males have no sting at all. The hymenopterans account for the majority of the severe allergic reactions caused by arthropods. The reactions to stings of honey bees, wasps, and fire ants vary from local swelling to fatal anaphylaxis.

There are many kinds of wasps, both solitary and social. Solitary wasps include the well-known mud daubers and velvet "ants" (species of wasps in which the females are wingless and antlike), and present a minimal stinging hazard unless grabbed or stepped on while barefoot. Social species, which include the yellow jackets, hornets, and paper wasps, build paper nests that they actively defend, and this results in many cases of stinging, particularly multiple stinging. Whereas solitary species only have males and females, social species have fertile females (queens); unfertile females (workers), which perform all tasks except egg-laying; and males (whose only function is to mate).

#### *Yellow Jackets*

In North America, the yellow jacket is the most common cause of hymenopteran stings. Yellow jackets (*Vespula*) are divided into several species groups based on differences in morphology, nest structure, biochemistry, and behavior. These include the *V. vulgaris* group (usually called *Paravespula* by European researchers), the *V. rufa* group, and the *V. squamosa* group. The first two are found throughout the Northern Hemisphere whereas the third is restricted to the New World. Most of them make their nests in the ground or at least within structures such as spaces inside walls or logs, and these nests may have several combs, all covered by a rather delicate protective envelope. Although most species have black and yellow coloration, some are black and white, and reddish patches may be present.

The *Vespula vulgaris* group includes many species that are primarily scavengers and build populous colonies, often containing several thousand individuals, that last well into late autumn or early winter. The species can be divided into several subgroups, but the species found in North America include *V. vulgaris* (transcontinental), *maculifrons* (eastern), *flavopilosa* (eastern, mostly upland), *pennsylvanica* (western), and the introduced *germanica* (mostly northeastern, now in some western areas, too). These insects become a stinging problem when their nests are disturbed (such as when mowing lawns) or when they are accidentally eaten with food when they visit picnics, and so on. *V. vulgaris* and *germanica* are important species in Europe, too, and have been introduced into several countries in the Southern Hemisphere as well.

The *Vespula rufa* group includes five American species (*vidua*, *consobrina*, *acadica*, *atopilosa*, and *rufa*) in addition to other species in

Europe and Asia. They tend to build rather small colonies of only a few hundred individuals. As workers are generally predaceous on other insects, they usually only become a problem when their nests are disturbed. Except for *V. atropilosa* (which is found primarily in western grasslands), the members of this group generally reach their greatest abundance in relatively cool, forested regions where they are less likely to be encountered except by loggers and recreationists.

The *Vespula squamosa* group includes only two species, one almost entirely restricted to California (*V. sulphurea*) and the other found throughout much of the eastern half of the US, especially the southeastern part (*V. squamosa*). The latter species, which is quite defensive when its nests are disturbed, tends to build its nests in lawns and other areas frequented by people. It exhibits both scavenging and predacious foraging behavior. Although colonies of yellow jackets, hornets and paper wasps are ordinarily annual, occasional colonies of *V. squamosa* manage to survive the winter in warmer areas; such colonies grow to enormous size during their second season. Queens of *V. squamosa* get a "head start" in the spring by taking over the nests of other species, especially *V. maculifrons*, and are unusual in that they do not resemble the workers in coloration (i.e., they are nearly solid brown instead of having the black and yellow bands of the workers).

#### Hornets

The genus *Dolichovespula* includes some so-called "hornets." In North America, the yellow hornet (*D. arenaria*) and the baldface hornet (*D. maculata*) are the most important allergenically. Both build paper nests resembling a gray bag hanging from a tree branch or the eaves of a building. They are primarily predators but become a problem when their nests are either accidentally disturbed or when built where work needs to be done (such as painting a house, trimming limbs, or lumbering). A few other species exist, but they are mostly restricted to high mountains and regions farther north than most urban development.

The yellow hornet is found in much of North America except for the southcentral states and lowland areas of the southeastern region. It is approximately the size and coloration of a yellow jacket. The baldface hornet is a larger insect, with most individuals being about an inch in length, and is mostly black with white on the face and white markings on the rest of the body, especially the last few segments of the abdomen. It is actually to be regarded as a beneficial insect because of its appetite for house flies as a source of protein for feeding its larvae.

Although no "true" hornets are native to North America, one species has been introduced from the Europe. This is *Vespa crabro*, the European hornet, which resembles a gigantic yellow jacket over an inch in length, and is established throughout much of the eastern United States.

This species usually builds nests inside hollow trees or empty spaces within walls, but occasionally its fragile sawdust-colored nests are suspended under eaves or along the walls of a shed. The workers capture many insects, including other wasps and bees, for use as larval food. When a nest is built close to a human dwelling, the insects have a tendency to fly to windows and artificial sources of light at night. The other species of *Vespa* are native to Asia and adjacent islands.

### *Paper Wasps*

There are many species of *Polistes* or paper wasps native to North America and throughout most tropical and temperate continents and large islands except New Zealand. These have a much more slender shape than the yellow jackets and hornets, and the nests do not have a protective covering around them; thus, they appear as individual exposed combs (however, the nests may be hidden inside a wall or other enclosed space). They are less agile flyers than the yellow jackets and hornets, and their prey tends to be mostly caterpillars. There are several groups of species.

*Polistes fuscatus* and its close relatives belong to a temperate New World group, and several species of widespread medical importance are included. *P. fuscatus* itself is an extremely variable species that may be black, brown, or red with a combination of yellow bands and red or yellow spots. It is found throughout most of the eastern half of the United States and adjacent southern Canada. Its close western relative is *P. aurifer*, which is generally yellow with blackish markings. *P. metricus* is a similar slightly-larger dark brown species that nests in dark enclosures throughout much of the southeastern third of the US. There are several other closely related species, some of which are reddish-orange while others are beige, the former being eastern and the latter primarily in southcentral and southwestern areas.

*Polistes exclamans* and *P. annularis* are members of a primarily tropical New World group, and reach their greatest abundance in the US in the southeastern part. *P. exclamans*, known in some regions as the "guinea wasp," is a relatively small wasp having conspicuous brown and yellow bands. Its rather lopsided comb is a familiar sight under eaves of buildings. *P. annularis*, known as the "red wasp" to fishermen in many areas, tends to build its combs, which are often the size and shape of a bicycle seat, among vegetation overhanging water. The insects themselves are slender, often over an inch long, and have most of the abdomen black with the remainder of the body reddish-brown. The specific name refers to the rather conspicuous ivory-colored "ring" on the end of the first abdominal segment.

*Polistes dominulus* is an introduced European species whose crisp black and yellow coloration resembles that of the yellow jackets. It is a

relatively small species, usually under an inch in length, and its nests are either under eaves or hidden inside structures. Initially having been discovered in Massachusetts, it has now been detected at least up to Maine, westward to Ohio, and southward to the DC area. It belongs to a species group otherwise restricted to the Old World.

### Bees

Bees may be either solitary or social. The former include, among others, the carpenter bees and sweat bees. Although sweat bees are not aggressive, they sometimes sting people because of their tendency to land on skin where they are accidentally squeezed. The social bees include the honey bees and bumble bees.

The honey bee (*Apis mellifera*) was introduced from Europe and is found throughout the US and most of the New World. Although most colonies are kept in man-made hives, swarms occasionally build their nests in hollow trees, spaces within walls, or (occasionally) suspended from tree branches. Exposed nests do not survive the winter, but those in enclosed spaces may survive for many years unless attacked by parasites or diseases. Honey bee colonies are perennial, surviving the winter by consuming the honey they have stored from the summer. Workers are about a half inch in length and generally of a combination of brown and orange, becoming black at the tip of the abdomen. The so-called “killer bees” are derived from African strains that were introduced into Brazil; although their behavior—in particular their aggressiveness—is different from that of the European strains, they are similar in appearance and individually no more venomous.

Bumble bees (*Bombus*) have an annual life cycle similar to that of the hornets and yellow jackets, but their food, like that of honey bees, is nectar and pollen. Their nests are composed of a collection of waxen “honey pots” and cocoons rather than a comb of hexagonal cells, and these nests may be made in a space in a wall, in the ground, in an old mouse or bird nest, or in any fluffy material such as upholsterer’s cotton. They are native throughout much of the world except for Australia, New Zealand (but where now naturalized) and Africa south of the Mediterranean region. They are black with hairs of various colors—usually black and yellow, but white, red, or brown may be present or even mixed.

### Ants

All ants are social insects developing perennial colonies, but there are relatively few species that present a stinging hazard in the United States. Of these, the fire ants (*Solenopsis*) and harvester ants (*Pogonomyrmex*) are noteworthy. There are five species of fire ants found in the United States, and two of these, which were imported from South

America during the 20th century, have presented a serious stinging hazard. The black species, *Solenopsis richteri*, became established in Alabama and Mississippi whereas the red species, *Solenopsis invicta*, can now be found from the Virginia Tidewater border southward to Florida, and then through the Gulf Coast region into central Texas, with introductions into New Mexico and California (and now established in the last state). The mound of each species resembles a large "pustule" of soil along roadsides and fields, and the ants immediately appear, ready to attack and sting, if the mound is disturbed. Each sting site results in a characteristic sterile pustule, and none of the other ants, including the other three species of fire ants, produce such pustules. The red species has displaced *S. richteri* such that the latter is now restricted to northeastern Mississippi and northwestern Alabama. There is evidence to suggest that the two are now hybridizing. Colonies of fire ants are perennial, as is the case for all ants. In addition, *S. xyloni* (southern fire ant), *S. geminata* (tropical fire ant), and *S. aurea* (desert fire ant) are occasionally responsible for allergic reactions. Their stings rarely produce pustules. However, the abundance of *S. xyloni* and *geminata* is being reduced by competition from *S. invicta*.

There are several species of *Pogonomyrmex* in the United States, and they are rather large ants, often with oversized heads, sometimes exceeding a fourth of an inch in length. Their nests are recognized as an entrance hole surrounded by a large patch of bare ground sometimes four or more feet in diameter. Most are restricted to the southwestern states, but one species ranges eastward to Florida and North Carolina (*P. badius*). Although harvester ants are much less aggressive than fire ants, individual stings are more severe and their venom is rather toxic.

### ***Nonstinging Insects, Mites, and Crustaceans***

Nonstinging insects fall into two categories: those that bite to suck blood, and those that cause allergy passively by their presence owing to hairs, scales, fecal material, or other allergens that become airborne. The former includes all the biting flies (order Diptera), including mosquitoes, and certain "true" bugs (order Hemiptera), whereas the latter include roaches (order Blattodea), caddisflies (order Trichoptera), and mayflies (order Ephemeroptera). Dust mites and crustaceans also fall into the "passive" category.

#### *True Flies (Diptera)*

The most important biting flies are the mosquitoes, horse flies, deer flies, black flies, and punkies. The word "biting" actually refers to the piercing of the skin by use of the insect's mouthparts and then the ingesting of the victim's blood. In addition to allergic reactions, the bites of

most of these insects cause irritation, and some are transmitters of diseases although not necessarily in the United States.

Mosquitoes, of course, are familiar to nearly everyone, and are probably the most important carrier, or vector, of diseases, especially in developing countries in the tropics where malaria, yellow fever, and other diseases are often prevalent. They belong to the family Culicidae. Only female mosquitoes bite, and the blood supply obtained is a necessary source of protein for the production of eggs; male mosquitoes feed only on nectar and plant juices. These insects range from the arctic to south temperate regions, and generally breed in water; a small amount sitting in a discarded can is more than adequate for some species. It is normal for a mosquito bite to result in localized swelling and itching.

Horse flies and deer flies belong to the same family (Tabanidae). The females feed by cutting into the flesh of animals, including people, and drawing up the blood ensuing from the wounds they create. Horse flies (*Tabanus*, *Hybomitra*) may exceed an inch in length, and are often black or dark gray whereas deer flies (*Chrysops*) are usually much smaller, many species being yellowish with some spots on the wings. They breed in water but may fly some distance from their breeding areas.

Black flies are small (less than a quarter inch), soft-bodied insects in the family Simuliidae that often attack in droves, especially in boreal regions, mostly in the spring and early summer. They breed in unpolluted quick-flowing streams where the larvae filter their food from the water. Although they are not known to transmit any diseases in North America, they do so in other regions of the world.

The punkies or “no-see-ums” (*Culicoides*) are tiny flies of the family Ceratopogonidae. The larvae develop in or near water, and the adults tend to remain nearby. The female fly has a bite that seems out of proportion to its size (which is generally less than an eighth of an inch), causing a burning sensation when feeding.

#### *True Bugs (Hemiptera)*

Some biting bugs include the conenose or kissing bugs (in the family Reduviidae) and bed bug (in the family Cimicidae). They feed by piercing the skin and sucking, in a fashion similar to that of the mosquito. The kissing bugs, of the genus *Triatoma*, are nearly an inch long and are occasionally associated with allergic symptoms, and they may transmit Chagas disease (uncommon in the United States but found in South America).

#### *Cockroaches (Blattodea)*

There are many kinds of roaches, and most of them remain outdoors. However, a few species, in particular the so-called American

roach (*Periplaneta americana*), the Oriental roach (*Blatta orientalis*), which are both in the family Blattidae, and the German roach (*Blattella germanica*) of the family Blatellidae are introduced (originally from Africa) and are pest species that often become established and abundant in houses and other buildings. Recent studies suggest that sensitization to cockroach allergens is common and is associated with the increase in prevalence of severe and fatal asthma in inner cities, especially among children of lower socio-economic groups. Infestation by domestic cockroaches is more likely to occur in low-income housing and in urban centers.

One or more of these three species can be found essentially throughout the country and most of the world. The American roach is a dark brown insect sometimes over an inch in length, and adults fly. The Oriental roach is very dark-brown but somewhat smaller with short, nonfunctional wings. The German roach is much smaller (approx a half inch in length), light brown, and a good flyer. Roaches tend to be objectionable because of their presence (although they apparently do not transmit diseases), the unpleasant odors they emit, and their leaving conspicuous fecal pellets (which are allergenic).

#### *Caddisflies (Trichoptera)*

Caddisflies are not true flies but rather are distantly related to moths. They sit with their wings held rooflike over their bodies. Their larvae live in water, and many species make distinct "cases" of sand or plant debris woven together with silk. The adults are sometimes attracted to lights and thus find their way into houses where the scales from their wings are allergenic to some people.

#### *Mayflies (Ephemeroptera)*

Mayflies are rather primitive insects that develop in water. They sit with their transparent wings folded vertically, and have a pair of long cerci or "tails" at the end of the abdomen. They are unique in that the winged form that emerges from the water is not yet an adult; this form molts (sheds its skin) again to become the adult. They live only a day or so and do not feed, but because many may emerge at once, the large amount of body hair and so forth may provoke an allergic response in some patients. In some areas, such as along Lake Erie, large numbers of mayflies used to emerge, die, and literally pile up on the shore.

#### *Moths (Lepidoptera)*

The order Lepidoptera ranges from the south temperate to arctic and alpine areas and includes many families of butterflies and moths. These insects typically have relatively large wings covered with scales. Most kinds of caterpillars are the larvae of members of this order, and

many species are agriculturally important because they consume crops and ornamentals as larval food. Several families, which include most of the day-flying forms that feed on nectar and are typically brilliantly colored, are grouped as the butterflies, whereas all the remaining families are considered moths; however, there is considerable diversity among the moths. Many species are of a subdued tan, gray, or brown color (often blending into their surroundings while resting) and are attracted to artificial sources of light at night. One large family, appropriately named Noctuidae, is especially abundant and includes many small or medium-sized rather thick-bodied species, but many other families are likely to be found resting near a source of light. The scales from the wings and body are removed quite freely, and this presents a source of allergy for some patients.

#### *Ladybird Beetles (Coleoptera)*

The order Coleoptera (beetles) is the largest insect order. The ladybird beetles belong to the family Coccinellidae. They are primarily predaceous on aphids (plant-lice). They hibernate as clusters of adults, often in dwellings where people may be exposed to them.

#### *Mites (Acarina)*

There are probably a million species of mites living in almost every conceivable habitat. Mites are arachnids, which makes them relatives of spiders, centipedes, and scorpions. Some species of mites often live in houses and feed upon the skin fallen from people, most notably *Dermatophagoides pteronyssinus*, *D. farinae*, and, in warm areas such as in southern Florida, *Blomia tropicalis*. These species, commonly referred to as “house dust mites” are frequently the major allergenic component of house dust and their allergens have been extensively studied. Although the mites themselves are essentially microscopic, they may reach astronomical numbers, and their fecal pellets contain potent allergens.

Occupational allergy owing to the spider mites, *Tetranychus urticae* and *Panonychus citri*, among fruit growers and greenhouse workers has been reported. Spider mite infestations of plants and trees may lead to significant levels of exposure for sensitization and work-related respiratory symptoms among these workers.

Spiders, centipedes, and scorpions, which are among the most conspicuous arachnids, are venomous although few are dangerous to humans; these are of importance owing to toxicity (rather than allergenicity) of their venoms.

#### *Crustaceans*

Crustaceans such as shrimp, crab, and lobster are a frequent cause of adverse food reactions in allergic individuals. Cross-reactivities

between crustacean allergens and allergens from mites and insects have been observed. It has been suggested that tropomyosin, a major crustacean allergen, is an important cross-sensitizing pan-allergen in these cases.

### Selected References

1. Lewis, W. H., Vinay, P., and Zenger, V. E. (1983), *Airborne and Allergenic Pollen of North America*. Baltimore, MD: The Johns Hopkins University Press.
2. Harlow, W., Harrar, E., Hardin, J., and White, F. (1991), *Textbook of Dendrology*. New York, NY: McGraw-Hill.
3. Solomon, W. R. and Mathews, K. P. (1988), Aerobiology and Inhalant Allergens, in *Allergy: Principles and Practice*, 3rd ed. Middleton, E. Jr., Reed, C. E., Ellis, E. F., Adkinson, N. F. Jr., Yunginger, J. W., eds. CV Mosby Co., St Louis, MO.
4. U.S. Department of Agriculture. Plants Database. <http://plants.usda.gov/>
5. Burge, H A. (1985), *Clin. Rev. Allergy* **3**, 319–329.
6. Alexopoulos, C. J., Mims, C. W., and Blackwell, M. (1996), *Introductory Mycology*. New York, NY: John Wiley & Sons, Inc.
7. St-Germain, G. and Summerbell, R. (1996), *Identifying Filamentous Fungi, A Clinical Laboratory Handbook*. Belmont, CA: Star Publishing Co.
8. Kendrick, B. (1992), *The Fifth Kingdom*. Waterloo, Ontario, Canada: Mycologue Publications.
9. Spitzauer, S. (1999), *Int. Arch. Allergy Clin. Immunol.* **120**, 259–269.
10. BIOSIS. Guide to the Animal Kingdom for Students and Educators. [www.biosis.org](http://www.biosis.org)
11. Akre, R. D., Greene, A., MacDonald, J. F., Landolt, P. J., and Davis, H. G. (1980), U.S. Department of Agriculture. Agriculture Handbook No. 552.
12. Arnett, R. H., Jr. (1997), *American Insects; A Handbook of the Insects of America North of Mexico*. Boca Raton, FL: CRC Press LLC.
13. Borror, D. J., Triplehorn, C. A., and Johnson, N. F. (1992), *An Introduction to the Study of Insects*, 6th ed. New York, NY: Harcourt Brace College Publishers.
14. Rhoades, R. B. (1977), *Medical Aspects of the Imported Fire Ant*. Gainesville, FL: Univ. Presses of Florida.
15. Krantz, G. W. (1978), *A Manual of Acarology*, 2nd Ed. Corvallis OR: Oregon State University Book Stores, Inc.