INTRODUCTION

In Europe, pollen allergy is the most typical form of seasonal respiratory allergic disease. However, in some regions of the world, pollen can be present in the air throughout the year. More than a quarter of a million pollen producing plant species have been catalogued, but of these, less than 100 are significant in terms of inducing allergy to their pollen in man. There are various reasons why only a minority of these species induce allergic reactions. In order to be allergenic pollen grains must:

- contain allergens able to elicit a specific allergic response in predisposed subjects
- be produced in high quantities and/or be produced by plants that grow in abundance
- be buoyant in air such that they can be carried long distances

Pollen (which contains the plant’s male gamete) may be transferred from the anther of the male flower (Figure 1) to the point of deposition by wind or by vectors such as insects (this is known as the pollination process).

![Figure 1: Schematic diagram showing the reproductive organs of plants.](image-url)
The method of pollination plays a key role in pollen-related allergy. Pollen from wind-pollinated plants is usually the most relevant source from an allergological perspective. Large amounts of buoyant pollen are produced by these plants in order to increase the probability of fertilising the stigma of a given female flower. In contrast, plants that use a self-pollination strategy (cultivated cereals such as wheat) or plants endowed with brightly coloured petals and nectar (e.g. roses or orchids) designed to attract the insects which mediate their pollination, are not allergologically significant. Unlike wind-pollinated plants, their large and heavy pollen grains are not sufficiently buoyant to reach substantial airborne concentrations.

The production, airborne flux and dispersal of pollens are strongly related to weather patterns. Certain pollens such as birch, are characterised by short seasons; others are present almost all year round in some regions (e.g. Parietaria). Moreover, the geographical distribution of a source plant has a crucial effect on the allergenic context (Figure 2).

![Distribution of pollens derived from grasses, olive trees and Parietaria in Europe during the month of June](image)

**Figure 2**

*Distribution of pollens derived from grasses, olive trees and Parietaria in Europe during the month of June*

The worldwide distribution of grasses, such as perennial rye and timothy and weeds, such as mugwort, account for their allergenic significance. Other plants are confined to discrete regions: birch occurs prevalently in the northern hemisphere; ragweed grows predominantly
in North America (but is now colonizing central Europe); *Parietaria* (a member of the nettle family) and olive trees grow mainly in the Mediterranean area; the Japanese cedar is largely restricted to Japan. Consequently, allergies to the pollen of certain plants will only tend to occur in discrete regions whereas allergies to common pollens, such as grasses, will be global in their effects.

Some plants produce high amounts of pollen and become allergenically important only where they grow in abundance (for example, the *Fagus* species (beech)). Lastly, some ornamental plants (for example, *Ficus benjamina* and mimosa) can be allergenic in subjects who live in their proximity, or encounter them occupationally, such as gardeners.

**Advice for Patients:** Although not highly allergenic, mimosa has been known to cause proximity pollinosis; it’s best to avoid smelling these flowers.

**POLLEN SHEDDING AND DISTRIBUTION (POLLINATION)**

Pollens are shed by the male part of flowers (anther). Changes in atmospheric humidity levels are the most frequent triggers leading to anther wall rupture and release of pollen. Depending on environmental factors and on the plant species, pollen can be shed into the atmosphere in a single burst or released gradually. These factors also govern the timing of pollen release. For most plants, pollen release occurs early in the morning (*Figure 3*).
The distance pollen travels from the plant depends on the nature of the carrying agent (wind, insects, etc.), environmental conditions and pollen size. For example, most grass pollen is deposited within 3 metres from the source; only 1% of grass pollen travels a distance of 1 km from the source. However, depending on the characteristics of the wind, pollen grains from some plants can be found 10 to 20 km distant from the source.

**Grasses**

Pollen produced by grass (Gramineae or Poaceae) is the major cause of pollinosis in many parts of the world, although its frequency differs regionally. The grass family comprises more than 600 genera and over 10,000 species. The most abundant airborne grass pollen originates from tall meadow grasses such as timothy (*Phleum pratense*), orchard grass (*Dactylis glomerata*), meadow foxtail (*Alopecurus pratensis*) and perennial rye (*Lolium perenne*). Cultivated rye (*Secale cereale*), is another potent source of allergens. Grass pollinates about 2-3 weeks earlier at sea level than in mountainous regions. Atmospheric concentrations of grass pollen are usually highest 1-2 months after the start of the main flowering season. With very few exceptions, grass-pollen types exhibit a very high degree of cross-reactivity. As a consequence, the allergy testing procedure used in patients needs to include only two or three species.

In common with other allergenic pollen grains, grass pollen allergens are rapidly released when pollen comes into contact with the mouth, nose or eyes, inducing the appearance of hay-fever symptoms in atopic subjects.

![Figure 4: Grasses (Gramineae).](image)


Members of this family are common throughout Europe.
Advice for Patients: To avoid exposure to pollen whilst inside your house, keep windows and doors closed during risk periods.

ALLERGENIC PLANTS IN EUROPE

Europe is a geographically and climatically complex continent with a wide diversity of climates ranging from the Arctic to the Mediterranean. The vegetation varies greatly within the continent. Allergy-inducing plants can be schematically divided into five main areas:

<table>
<thead>
<tr>
<th>Region</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Birch, grasses</td>
</tr>
<tr>
<td>Central</td>
<td>Deciduous forest trees, birch, grasses</td>
</tr>
<tr>
<td>Eastern</td>
<td>Grasses, mugwort, ragweed</td>
</tr>
<tr>
<td>Mountainous</td>
<td>Grasses, trees</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>Grasses, Parietaria, olive, cypress</td>
</tr>
</tbody>
</table>

Over the last twenty five years, respiratory allergy has had a remarkable clinical impact throughout Europe. There is evidence that the prevalence of allergic reactions induced by pollen is increasing. Between 8 and 35% of young adults in EU countries exhibit IgE serum antibodies to grass pollen allergens. Grass pollen is by far the most frequent cause of pollinosis in Europe.

It is interesting to note that in various European cities, such as London, Vienna and Naples, that, whilst the prevalence of allergic rhinitis and allergic asthma is increasing, the atmospheric concentration of grass pollen is decreasing. The decrease in grass pollen concentrations has been attributed to a substantial reduction in grassland cover over large areas of the continent. In fact, the last 20 years has seen a decline of about 40% in European grassland. However, the observation that cases of allergic rhinitis and asthma induced by grass pollen are increasing is probably accounted for by multi-factorial explanation and includes increased air pollution.

In northern, central and eastern Europe, the main grass flowering period starts at the beginning of May and finishes at the end of July. In Mediterranean areas, flowering usually starts and ends one month earlier. In northern Europe, pollen from the Betulaceae family (Birch tree) is a major cause of allergy. However, in the context of allergenic trees, hazel and alder are the first to shed pollen in Europe, followed by Birch. As a consequence of their early pollination and of the allergenic cross-reactivity, hazel and alder can act as primers of allergic sensitization to birch.
Commonly found in Northern and Central Europe

Owing to its characteristic climatic conditions; mild winters and dry summers, the vegetation of the Mediterranean area is totally different from that of central and northern Europe.

In the Mediterranean area there are three pollen seasons:

- A low winter pollen season (from December to the end of March) marked by the presence of the pollens of such trees as Cypress and Juniper (Cupressaceae), Hazel (Corilaceae), Mimosa (Acaciae) and Birch (Betulaceae).
- A high spring-summer pollen season (from April to July), dominated by the pollination of Grasses, some members of the nettle family (Parietaria) and olive trees (Olea). Slightly overlapping this season, from March to May, Platanus flowers (such as American sycamore) have some allergenic importance in Mediterranean areas e.g. southern France, Spain etc.
- A summer-autumn season (from August to October) containing the second, less pronounced, peak of Parietaria (and sometimes of Gramineae) and the pollens of herbaceous plants, such as mugwort and Chenopodiaceae (Beta vulgaris which includes beet, sugar beet, and chard, and wild spinach).

Classical examples of allergenic-pollen-producing plants typical of the Mediterranean climate are Parietaria (nettle family), Olive and Cypress (Cupressaceae).
Native to Mediterranean Areas.

Parietaria (a member of the nettle family) is responsible for many cases of severe pollinosis and has two lengthy flowering periods. Its pollen first appears in early spring and persists into the summer months. Daily mean values of more than 2 hundred pollen grains per cubic meter can be encountered at the end of April or in May, depending on the climate of the area.

The extraordinarily long atmospheric persistence of Parietaria pollen in the Mediterranean area is responsible for persistent allergy symptoms in sensitive individuals. Bronchial asthma or other respiratory symptoms, such as cough (severe in some cases) associated with rhinoconjunctivitis, is present in more than 50% of patients living in some Mediterranean areas, e.g., southern Italy, Spain and Greece who are sensitive to Parietaria pollen. In the olive tree family (Oleaceae), the most allergenic pollen is produced by *Olea europaea*. In the Mediterranean area, the olive pollen has been recognized as one of the most important causes of seasonal respiratory allergy. The olive pollination season lasts from April to late June and sometimes causes severe symptoms (rhinoconjunctivitis and/or bronchial asthma) in sensitive subjects.

Frequently, sensitization to olive tree pollen allergens is associated with other allergic sensitizations such as sensitization to grasses; it is difficult to identify the prevalent source of sensitization in such cases. Another interesting aspect of olive pollen allergy is that the clinical symptoms are frequently not limited to the pollination season (May-June) but are present all year round in sensitive subjects although the underlying reason has yet to be established.
Figure 7 Olive:

Native to Mediterranean Areas.

Cypress trees are increasingly being used for gardening and reforestation in Europe, particular in Mediterranean areas. Together with Hazel (Corylus), Cypress pollen is now the most common airborne allergen in Europe during the winter months. The mounting epidemiologic impact of pollinosis induced by Cypress is directly related to the increasing use of these trees. As with the planting of birch trees, this is a case of arboreal fashion influencing the epidemiology of pollen-induced disorder.

Ragweed (Ambrosia elatior or Artemisiifolia) cover is increasing in central Europe. Short ragweed originated from the USA and rapidly spread within Europe from two points; the Rhone valley in France and, to an even greater extent, in eastern Europe (Hungary and the Balkan States). Ragweed plants and airborne ragweed pollen have also been reported from northern Italy, Poland, the Czech and Slovak Republics Byelorussia and Russia. The main flowering period is from mid August to mid September.

Figure 8; Ragweed:

Most commonly found in Central and Eastern Europe

© The UCB Institute of Allergy - 09/2007
Advice for Patients: In order to enjoy your well-earned break, select holiday destinations that are not high risk for your type of allergy. The pollen count is usually low at the seaside and high in the mountains. An exception is Parietaria that flowers around Mediterranean coastal waters.

POLLEN-FOOD ALLERGY (ORAL ALLERGY SYNDROME)

Pollen-Food Allergy (also known as Oral Allergy Syndrome or OAS) results from a cross-reactivity reaction between allergy antibodies raised against pollen proteins with similar proteins that are found in other parts of plants. Itchiness of the mouth and throat with mild angioedema (swelling) immediately after eating fresh fruits or vegetables are common symptoms of OAS. Individuals with ragweed allergies might experience these symptoms when consuming foods such as: banana, cucumber, melon, zucchini/courgette, sunflower seeds, chamomile tea or echinacea.

This syndrome is also common in people with birch tree pollen allergies. Foods that can trigger a reaction in people with this allergy are: peach, apple, pear, cherry, carrot, hazelnut, kiwi or almonds.

Those subjects allergic to grasses may experience reactions when eating: wheat, tomato, kiwi fruits, melon, watermelon, peach, cherries or apricots and those with a sensitivity to parietaria can react to basil, mulberry, cherries and melon.

In many cases, cooking the food will denature the proteins and prevent any reaction. However, this is not always the case and in highly allergic individuals symptoms may include severe swelling of the throat or systemic reactions.

Advice for Patients: If you know you are allergic to ragweed, birch, grasses or Parietaria, remember that you may also react to certain foods.

INTERRELATIONSHIP BETWEEN OUTDOOR AIR-POLLUTION, CLIMATIC CHANGES AND POLLEN-RELATED RESPIRATORY ALLERGY

Several studies have shown the adverse effects of ambient air pollution on respiratory health. Allergic respiratory diseases such as hay fever and hay asthma have become more common in the last two decades throughout the industrialised world although the reasons for this increase are still the subject of debate. However, despite evidence of a correlation between the increasing frequency of respiratory allergy and the increasing levels of air pollution, the exact nature of the link and interaction between the two elements is still
speculative. The confounding factors which make it difficult to interpret the results of several studies on this topic include cigarette smoke, exposure to indoor pollutants and to aeroallergens (outdoors and indoors) in atopic subjects sensitized to more than one allergen. However, even if it is plausible that ambient air pollution plays a role in the onset and increasing frequency of respiratory allergy, it is not easy to show that this happens at a public health level. In addition, it is important to recall that an individual’s response to pollution exposure depends on the source and components of the air pollution event in question and climatic factors. Indeed, some air pollution-related incidents of asthma aggravation relate to climatic factors that favour the accumulation of airborne pollutants at ground level rather than increases in atmospheric pollution levels per se.

There is evidence that living near roads that have a high traffic density is associated with impaired respiratory health. Road traffic with its gaseous and particulate exhaust emissions is currently, and is likely to remain, the main contributor to air pollution in most urban settings. Air pollution is convincingly associated with many signs of asthma aggravation (expressed by increased bronchial hyperresponsiveness; need for visits to emergency departments; need for hospital admission, increased medication use etc). Moreover, sensitive techniques which have been used to analyse time-series data have shown that there are clear adverse effects on mortality rates from current levels of air pollution. In a study of six US cities, a significantly increased mortality rate was observed in the most polluted areas in comparison to the least polluted regions, after adjusting the data for risk factors such as smoking etc. Governments and international organizations such as the World Health Organization and European Union are facing a growing problem of reconciling the respiratory effects induced by gaseous and particulate pollutants arising from motor vehicle emissions with the requirements of sustainable economic development.

Figure 9
Pollution from motor vehicles can exacerbate allergic reactions
The most abundant airborne pollutants in urban areas with high levels of vehicle traffic are respirable particulate matter, nitrogen dioxide and ozone. It is estimated that more than 50% of the population of the USA live in areas that exceed the current National Ambient Air Quality Standards for ozone, nitrogen dioxide, sulphur dioxide and particulates, set by the US Environmental Protection Agency. In general, the effects of air pollutants on the nose and lung depend on the environmental concentration of the pollutant, the duration of pollutant exposure and the total respired air volume of the exposed person.

Aeroallergens, e.g. those derived from pollen grains, lead to rhinitis and bronchial obstruction in predisposed subjects and one of the most frequently used models to study the interrelationship between air pollution and respiratory allergic diseases has been pollen allergy. It has been suggested that air pollutants may promote airways sensitization by modulating the allergenicity of airborne allergens, making them more deleterious. Pollen allergens can be carried in the atmosphere by a component of air pollution such as inhalable particulate matter and, conversely, airborne pollen grains can act as carriers of some particulate components of air pollution. There is also evidence that air pollution can cause damage to the nose and lung mucosae and may facilitate the penetration and the access of inhaled allergens.

Advice for Patients: When travelling by car through risk areas, keep your car windows closed. Ensure that the air conditioning is equipped with a filter and remember to change the filter periodically.

Interaction between air pollution and allergenic vegetation

Vegetation is affected by air pollution over a wide range of pollutant concentrations and environmental conditions. Many factors influence the interaction, including type of air pollutants, plant species, the plant’s nutrient balance, soil conditions and climatic factors. At low exposure levels for a given species and pollutant, no significant effects are observed. However, as the exposure level increases, a series of potential injuries may occur to the plant (biochemical alterations etc.).

Components of air pollution can influence the plant allergenic content. By affecting plant growth, air pollutants can affect both the amount of pollen produced and the amount of allergenic proteins contained in pollen. A study showed that the pollen grains of plants stressed by air pollution express enhanced levels of allergenic proteins. Moreover, birch
trees exposed to high levels of air pollutants are characterized by higher levels of pollen
antigen than trees growing in areas with lower levels of air pollution.
It has been also observed that exposure to nitrogen dioxide adversely affected the pollen
germination of various trees (birch, alder and hazel) and so altered their protein content,
including allergens. Pollen grains collected from roadides with heavy traffic density and
from other areas with high levels of air pollution are covered with large numbers of airborne
micro-particulates (usually less than 5 micrometres in diameter).
Of airborne particulate emissions, much interest has been focussed on diesel exhaust
particulate (DEP) because experimental studies showed that DEP can modify the immune
response in predisposed animals and humans. In fact, DEP seems to exert an adjuvant
immunological effect on IgE synthesis (IgE are the antibodies responsible for allergic
diseases) in atopic subjects, thereby influencing sensitization to airborne allergens. We hope
that new diesel engine designs will be able to reduce DEP emissions into the atmosphere.

Experimental studies in which allergic asthmatics are exposed to either ozone or non-
polluted air prior to allergen challenge, showed an increased sensitivity to inhaled allergens
in subjects pre-exposed to ozone compared to those pre-exposed to non polluted air. In
other words, less inhaled allergen was required to cause a bronchospasm (asthma crisis)
after ozone exposure.

Measures which may reduce the impact of urban air pollution on allergy include:

- Reducing the pollution levels by:
  - Limiting the use of private cars in towns and even stricter control of vehicle
    emissions.
  - Decreasing the use of fossil fuels and increasing the use of alternative energy
    sources.

- Reducing the levels of allergens in built up areas by:
  - Planting trees in urban settings which are non-allergenic.

- Reducing the impact of these factors on allergic individuals by:
  - Increasing dietary consumption of anti-oxidant foods.
  - Improving nasal function (for example via the use of antihistamines) which
    could then protect the lower airways.
Interaction between thunderstorms and asthmatic attacks in pollen-sensitive individuals

Thunderstorms have been linked to asthma epidemics, especially during the pollen seasons. Such epidemics have been reported in various cities, mainly in western Europe (Birmingham and London in UK and Naples in Italy) and Australia (Melbourne and Wagga Wagga). Pollen grains can be carried at ground level by the strong air currents often associated with thunderstorms; during these events, the likelihood of pollen rupture as a result of osmotic pressure is increased. Consequently, allergenic aerosols derived from the cytoplasm of the pollen grain, are generated with particle sizes at the sub-micron level. Such aerosols can be readily inhaled and can penetrate deeply into the lower airways inducing asthma reactions in pollinosis patients.

The thunderstorm-asthma outbreaks are characterized, at the beginning of the storms, by a sudden increase in the number of patients visiting their general practitioner or hospital emergency departments with asthma symptoms. Indeed, subjects affected by seasonal rhinitis with no history of asthma may experience an asthma attack during thunderstorms.

No unusual air pollution levels were noted at the time of the epidemics reported in the cities mentioned above, but there was a strong association with high atmospheric concentrations of pollen grains such as grasses or other allergenic plant species. Subjects affected by pollen allergy should be informed about the possible risk of asthmatic attack during thunderstorms occurring during the pollen season.
Air-pollution, climate changes and pollen-related respiratory allergy.

The role of climatic factors (e.g. barometric pressure, temperature and humidity) in the triggering and/or exacerbation of respiratory allergic symptoms in predisposed subjects is still poorly understood. For example, while the relationship between thunderstorms and exacerbation of pollen allergy during the pollen season has been demonstrated for some plant species such as grasses, the relationship between respiratory allergy and barometric pressure is not clear. Indeed, asthma crisis have been linked not only with low atmospheric pressure but also with high pressure. Therefore, more studies are required to clarify this issue.

Exercise increases oral breathing, allowing greater penetration of inhaled particles into the airways. Taking exercise in polluted areas results in greater deposition within the lungs of airborne pollutants such as particulate matter, including particles carrying allergens.

There is also the thorny question of how increasing levels of greenhouse gases and concomitant climate changes will influence the frequency and severity of pollen-induced respiratory allergy. A variety of direct and indirect evidence suggests that climate changes may affect pollen release and consequently pollen-related allergies. In fact, climate variations are likely to influence vegetation with consequent changes in growth, reproductive cycle, etc.

Consequently, this will influence the production of allergenic pollen (seasonal period becoming longer with increased intensity) with greater proliferation of weed species. Climate changes will vary from region to region: some areas will be subject to increases in ultraviolet radiation and/or rainfall frequency whereas other areas will see reductions in these parameters. Moreover, ultraviolet radiation in a polluted urban atmosphere favours the formation of ozone. Elevated ozone levels coincide with maximum daytime temperatures, low wind speeds and clear skies (an association characteristic of the Mediterranean area). Ozone is the most important component of the so-called “summer smog” and is produced by photochemical reactions induced by ultraviolet radiation on mixtures of nitrogen dioxide and hydrocarbons in the atmosphere. It has also been observed that ozone exposure can increase the sensitivity of an allergic patient to allergens. The compound itself is harmful to the nose and the lungs, particularly of allergic asthmatic subjects.

Weather may affect levels of other pollutants commonly associated with asthma exacerbation (sulphur dioxide, nitrogen dioxide and particulate matter). In particular, temperature inversions are usually associated with the highest levels of particulate matter, sulphur dioxide and NO₂.
CONCLUSIONS
The frequency of pollen allergy has clearly increased in recent years. The disease was rare when it was first described as summer hay fever 150 years ago. In 1876 Blackley wrote that the frequency of pollen allergy was increasing, especially in industrialized countries. Nowadays the prevalence of pollen allergy is has been estimated as ranging between 9 and, in some regions, 42 %

Pollen-related allergies are common in inhabitants of large cities, but somewhat less prevalent in rural areas. Allergy develops as a result of multiple interactions between the human immune system and the environment. The current state of knowledge does not permit the importance of genetic and environmental factors to be precisely evaluated. Although genetic control is very important, environmental influences seem dominant in determining the specific allergens to which a person will develop hypersensitivity.

The adjuvant factors of the environment play an important role in the increasing problem of pollen allergy in large cities. Air pollution such as, ozone, nitrogen oxides, sulphur dioxide, occupational dust, organic and inorganic suspended particulate matter, tobacco smoke, etc., can cause an increase in airways reactivity.

All these factors, irritating the airways, permit pollen grains to penetrate deeper into the human body. As a consequence, the increased airways inflammation can enhance the risk of infection. Air pollution may also increase the development of pollen allergy through a direct influence on the pollen grains (on their enzymes, plant growth etc.) and pollens may carry on their surfaces the various substances which are known as environmental allergens.

Over the past two decades there has been increasing interest in studies of air pollution and its effects on human health. Although the role played by outdoor pollutants in allergic sensitization of airways has yet to be clarified, a body of evidence suggests that urbanization, with its associated high levels of vehicle emissions, and a westernized lifestyle are linked to the rising frequency of respiratory allergic diseases seen in most industrialized countries. Climatic factors (wind speed, temperature, humidity etc) can affect both components (biological and chemical) of this interaction. Fortunately, there is a burgeoning of research activity and a drive by both national governments and international organizations to set new health-based air quality standards based on the latest research designed to protect the public. It is of great importance to investigate to what extent the use of alternative fuels or engine types can reduce the formation of ozone. However, important decisions need to be taken urgently by governments worldwide concerning motor vehicle induced air pollution to reduce the future costs of effects on health and on the environments.

Prof. Gennaro D'Amato
FURTHER READING

Pollen-related allergy in Europe. Position Paper of the European Academy of Allergology and Clinical Immunology.
Allergy 1998;53:567-57

D’Amato G., Spieksma F. Th. M., Bonini S. (Eds):
Allergenic pollen and pollinosis in Europe.

D’Amato G, Holgate S.
The Impact of Air Pollution on Respiratory Health.
Monograph of the European Respiratory Society. Sheffield, UK, 2002

D’Amato G, Liccardi G, D’Amato M, Holgate ST.
Environmental risk factors and allergic bronchial asthma.