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CHAPTER 5

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Interaction between air pollutants and aeroallergens

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Introduction

5.1. Despite the recent interest in the possibility of a link between air pollution and allergic disease there has been scant attention given to the interactions and relationships between aeroallergens and air pollutants either in the outdoor or indoor environment. This paper reviews the current awareness of this theme from four main aspects.

(a) The effects of air pollution on the abundance and chemical structure of aeroallergens.
(b) The allergenic potential of non-pollen aeroallergens, such as micronic and submicronic allergenic particles, volatile organic compounds and fungal spores, in polluted environments.
(c) The indoor environment.
(d) Patterns of long-term changes in the abundance of the main aeroallergens outdoors, and the seasonal and regional coincidence of aeroallergens and air pollutants.

The effects of air pollution on aeroallergens

Introduction

5.2. Aeroallergens in the outdoors environment include pollen and spores, their derivatives, and material from other sources such as plant sap, anther linings and leaf leachate. Air pollution can influence the abundance and chemical nature of aeroallergens through indirect action by reducing plant productivity and through direct action by altering allergenic proteins. To some extent these influences lead to conflicting results; the first tends to reduce the allergen load in the atmosphere whilst the second generally seems to render allergens more potent. Considerable uncertainty exists about the scale and significance of the processes operating.

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Pollen size and abundance

5.3. Air pollutants induce stress on a wide range of plant types through a variety of mechanisms, including interference with the chemical pathways of photosynthesis, root injury by mobilization of trace elements and increased foliar leaching [38]. Reduced net productivity typically results in a decrease in the total amount of pollen produced and also in the size of individual pollen grains [39]. Research on this topic has not concentrated on allergenic pollen but it is reasonable to suppose that the general reactions are similar in many types of plant. For example, in a study of Japanese pear trees growing in conditions of different air pollution exposures, Omura [40] found that pollen grain numbers were greatly reduced in polluted areas. Similarly, Troumbis [41] found that pollen production of *Thymus capitatus*, decreased in areas of Greece which experienced high concentrations of air pollution and concluded that this resulted from an indirect effect of pollution on soils rather than a direct result of air pollution acting on pollen development. Laboratory experiments have demonstrated the influence of individual pollutants. For instance, Jain and Chauhan [42] found that SO_2 fumigation of *Capsicum annum* reduces the number of flowers per plant. In addition to this effect, the size of the pollen grains may be reduced, as demonstrated by Salgare [43], who examined pollen from a range of angiosperms (flowering plants) in areas subject to industrial pollution and found significant reductions in the pollen dimensions for some species.

Pollen viability

5.4. Numerous investigations have reported a reduction of pollen viability in grains contaminated by air pollutants. Most of these studies have not analysed chemical changes in pollen wall proteins resulting from exposure to pollutants but have concentrated on physical manifestations such as lack of germination of the grain or retardation of pollen tube growth.

5.5. The relevance of these studies to allergy lies in the fact that the pollen wall proteins play a key role both in

intraspecific chemical recognition for pollination and in allergic reactions in humans. Most flowering plants have evolved ways of recognizing pollen from their own species. Within a few seconds of landing on the stigma the pollen grain discharges types of protein that are distinct for that species. The grain will not germinate and grow effectively if the chemical signature is incorrect. Evidence from a wide range of botanical studies supports the hypothesis that the chemical structure of the allergens held on the walls of pollen grains is altered when exposed to pollutants. This changes pollen viability although it is clearly not the only cause of infertility.

5.6. Amer [44], Jain and Chaudan [45], and Krug [46] all reported that the pollen grains from a variety of plant species fumigated with SO_2 showed a significant decrease in fertility and that the incidence of small and deformed grains increased. Kandasamy and Kristen [47] found that laboratory exposure to triethyl lead retarded pollen tube growth in tobacco. During investigations of the influence of pollutants in the ambient atmosphere on pollen grains of *Pinus pinea* in Italy, Renzoni [48] noted significantly lower pollen fertility and more anomalous (wrinkled, reduced size, distorted) grains in Pisa town centre compared to the rural site of San Rossere, National Park. Concentrations of pollutants were not detailed. Similarly, when Pogosyan [49] examined pollen sterility in grape in Armenia, fertility was found to be lower.

5.7. Several workers have investigated the effects of photochemical pollutants either singularly or in combination and some have considered the synergistic effects of pollutants with increased exposure to UV light. Portyanko [50] conducted laboratory experiments on several species of angiosperms fumigated with NO_2, SO_2, NH_3 and H_2S. He concluded that SO_2 and NO_2 were generally more toxic than the other compounds with regard to pollen germination. At 0.1% concentration, SO_2 and NO_2 were more toxic then NH_3 and H_2S. Trials were conducted for all four pollutants at concentrations from 0.001–0.5% over 12 hours in laboratory chambers with pollen on a medium of 2% agar and 10% sucrose. Feder and Shirer [51] working in the U.S.A., reported that the combined effects of UV-B and O_3 reduced pollen tube growth more than either stress alone, but did not explore the reasons for this. Similarly work in ambient atmospheres in Canada by Comtois [52] indicated that pollen viability of White Birch (*Betula payrifera*), Yellow Birch (*Betula alleghaniensis*) and Sugar Maple (*Acer saccharum*) is reduced in areas of high ozone concentrations. In areas with maximum daily concentrations of 80 ppb O_3, and mean daily O_3 concentrations during May 1988 of 34–70 ppb, pollen viability was 27% lower than in areas with very low ozone concentrations.

5.8. Pollen from angiosperms appears more susceptible to pollution damage than that from gymnosperms (cone-bearing seed plants). For example Paoletti [53] deduced the influences of SO_2 and NO_x though their contribution to acid deposition. A growth medium of pH 4.0–5.0 inhibited pollen germination more in 13 broadleaved species, e.g. *Quercus* Spp. (Oak), *Fagus sylvatica* (Beech), *Acer pseudoplatanus* (Sycamore) than in six conifer species, e.g. *Cedrus* spp. (cedar), *Pinus* spp. (pine). Conifer pollen germinated at acidities as low as pH 2.5 or 3.0. Among the angiosperms the pollen from anemophilous (wind pollinated) plants was found to be more susceptible to pollution damage than that from entomophilous (insect pollinated) species. The higher resistance of entomophilous pollen could be due to the presence of a thicker layer of tryphyne (an oily substance composed mostly of lipids with pigments and proteins) on these grains. Anemophilous pollen is generally more important than entomophilous pollen in causing allergic reactions, partly because it is far more prolific in the atmosphere.

5.9. In conditions of high relative humidity the surface of the stigma can absorb gaseous pollutants such as sulphur dioxide and nitrogen dioxide, converting them to acids in the tissues. The subsequent change in pH will retard pollen tube growth.

5.10. Hjelmroos *et al.* [54] collected pollen from 100 marked birch trees exposed to different levels of pollutants. They found that pollen from trees in urban areas exposed to traffic fumes, had decreased antigenicity when compared to pollen from trees growing in rural areas with very low car density.

Direct effects on allergens

5.11. Ruffin *et al.* [55–57] determined that gaseous pollutants such as NO_2, SO_2 and CO exert a direct effect on the allergenic proteins held in the pollen grain wall at 1% (10,000 ppm). Previous studies by this group and others had indicated that there is a close relationship between the free amino acid content and the allergic potential of pollen grains. Ash, Elm, Ragweed and Sorrel all appear to have a high free amino acid conent. Tests on pure pollen grains of Red Oak (*Quercus rubra*), Meadow Fescue (*Festuca elatior*) and Chinese Elm (*Ulmus pumula*) revealed that, after exposure to these pollutants, the free amino acid concentration increased. Electrophoretic studies showed that these gaseous pollutants in combination have a profound effect in decreasing the molecular weights of allergens. Qualitative analysis demonstrated that in some cases the different treatment produced different amino acids. The authors suggested that after contamination certain peptides broke down and released particular amino acids which were not present in the control extracts. In a few

cases the free amino acid content decreased, especially in the Fescue contaminated with NO_2, SO_2 and CO in combination.

5.12. The antigenicity of extracts from the Red Oak pollen contaminated with NO_2, SO_2 and CO individually was assessed in comparison with controls. Immunodiffusion was used to observe the formation of IgG antibodies in rabbits after injection with the treated and untreated extracts. The binding patterns from immunodiffusion plates showed that the interaction of Red Oak pollen wall antigens with their corresponding antibodies changed after exposure to the pollutants. In particular the extracts treated with NO_2 exhibited marked changes. Results of work conducted by Santra [58] on a similar theme concur with those from Ruffin *et al.*

5.13. More research is required to determine the detailed chemical composition of all allergens present after pollutant exposure but the work completed so far gives reason to suspect that as the pollen grains travel through polluted air the pollen wall proteins may become modified to increase their potential to cause allergic disease. This has implications both for local environments and for long-range transport. Several accounts describe long-distance travel of pollen into Scandinavia [59] in which symptoms of seasonal allergic rhinitis occurred before the onset of local anthesis. In most cases the trajectories of the associated air-flows show that the imported pollen would have been exposed to considerable pollution load en route.

Non-pollen aeroallergens

Micronic and submicronic particles

5.14. During the last ten years the existence of micronic and submicronic allergen-bearing particles has been clearly demonstrated for several plant groups including ragweed [60], Red Oak [61] and grass [62]. These particles and aerosols which have been detected as small as 0.1 μm in diameter, may originate directly from plant material or they may form by combination or reactions with air pollutants. Evidence suggests that in the latter case potent aeroallergens are formed. As these are of respirable dimensions, they may penetrate deep into the lung and could invoke asthma attacks.

5.15. The most frequently used method for sampling micronic and submicronic particles in this context is with high volume samplers (HVS) which have flow rates up to 1.2 m^3/min. They are usually combined with cascade inpactors to fractionate particles by size classes. Particles are captured on large filters. The allergen content of the various particle size classes within the sample is typically determined by RAST [63] but some workers have used ELISA [64]. The exact origins of micronic and submicronic allergen-bearing material are unknown but it is likely that several mechanisms are involved and that their relative importance varies according to climate, habitat and pollution load. Solomon [65] suggested that one possible source is from pollen fragments formed by physical degradation of grains in the environment. However palynologists do not consider that this would make a substantial contribution. Pollen grains are generally robust and resistant to abrasion in dry air. In the time taken for a pollen grain to break into fragments it is likely that the proteins in the wall would be leached out by contact with moisture.

5.16. Knox [66] emphasized the importance of the starch granules which may be released when grass pollen grains rupture in rainfall. The immunodominant component of Rye grass, Lol pI, is located mainly on the external surface of the cell but a newly identified allergen, Lol p IX [67] is located mainly in the starch granules within the pollen grain. Knox points out that a single mature Rye grass pollen grain contains about 700 starch granules in the size range 0.6–2.5 μm. These constitute a potential source of micronic and submicronic allergenic particles. He developed the hypothesis that the starch granules might be responsible for triggering epidemics of asthma amongst grass-sensitive patients during episodes of thunderstorms in parts of Australia but did not consider the potential role of other agents, such as fungal spores. Pollen grains will usually rupture only when fresh and when the final maturation stage in the anther has been completed.

5.17. Another possible source of submicronic particles bearing allergens is from plant material other than pollen. Fernandez-Caldas *et al.* [61] suggested that Red Oak pollen allergens in small particles originated from decaying leaves, male catkins and other plant material. This deduction was based on observed correlations between micronic particle occurrence, pollen seasons and weather factors. In this context Knox [68] indictated that a contribution may derive from obicules (spherical particles 0.02 μm in diameter) on the anther lining in some plant groups including ragweed and grass. These bodies, which may be released to the airflow, consist of sporopollenin, the same biopolymer as pollen. In addition, to these non-pollen sources, evidence suggests that some allergens may become airborne as aerosols from sap, for example when lawns are cut. Ledford *et al.* [69], Morrow-Brown [70] and Fernandez-Caldas [71] have demonstrated that grass allergen is present is the leaves of lawn grasses. This supports the hypothesis that allergen aerosoled from the leaves during mowing contributes to the symptoms of allergic individuals as suggested by Rowe *et al.* [72]. Allergen activity has also been found in leaves of other plant types, including ragweed [73].

5.18. Many research projects have demonstrated that airborne allergens may be detected in the atmosphere prior to the pollen season and that they persist along after pollen is no longer present in the air. It has also been shown that in some locations during the peak ragweed pollen season almost 50% of the total allergen is associated with particles of less than pollen grain dimensions [74]. Similar results have been reported with respect to *Alternaria* spores.

5.19. Whatever the origin of the micronic and submicronic particles bearing allergens, there is clearly a potential for interaction with air pollutants by binding with suspended particulate matter (SPM) or diesel exhaust particles (DEP). This may increase the potential of the allergens to sensitize individuals (see Chapter 10).

Volatile organic compounds

5.20. Some evidence indicates that volatile organic compounds (VOCs) given off by plants can affect hayfever sufferers. Substances include those in the scents of flowers and chemicals emitted for defence against insects. Little work has been done on the chemical nature of these compounds but it has been suggested that some act as irritants rather than as allergens. Volatiles given off from oil seed rape consist of S-methyl cysteine suphoxide and the metabolic breakdown products of glucosinolates. These exist in many forms and are widespread through the plant kingdom [75]. The role of VOCs from oil seed rape is being considered in the current debate about the allergenicity of this crop but there are no clear conclusions to date [76].

5.21. Many studies report the onset of symptoms of seasonal allergic rhinitis before the start of the pollen seasons. In the case of people who are sensitive to tree allergens, Swedish researchers suggest that the reaction is a response to VOCs released from buds as they swell and open in the spring. However only a minority of people are likely to be affected by volatiles in the outdoor environment. They disperse rapidly in the atmosphere and would probably be active only near their source.

5.22. Very little work has been done on the interactions between VOCs and air pollutants but there are several issues to consider:

(a) the role of natural VOCs in the transformation of ozone;
(b) the extent to which VOCs prolong/enhance the season of exposure and whether this causes more interaction with pollutants;
(c) reactions between natural VOCs and particulate air pollutants.

Fungal spores

5.23. Current estimates suggest that between 2 and 30% of the population are allergic to fungal spores but very little research has been conducted on the detailed aspects of the allergens from this group. This is partly because fungi are very varied and complex. For example, *Alternaria alternata* has 14 strains and *Aspergillus fumigatus* has 29 strains, all with high mutation rates and allergen specificity. A considerable amount of work has been done on the characterization of the allergens of *Alternaria*, *Aspergillus* and *Cladosporium* but little research has been done on other genera, variation within each genus and on cross reactivity.

5.24. In view of this, it is not surprising that virtually no work has been done on the interactions between fungal allergens and air pollution. However it is likely that allergy due to fungal spores would be aggravated by the presence of air pollutants. Fungi can grow in virtually every habitat both indoors and out. Most fungal spores are very small (e.g. *Aspergillus* 3–7 μm, *Cladosporium* 10 μm) and in many cases the mycelia can produce mycotoxins of low molecular weights. Under conducive environmental conditions spores can be present in very high concentrations and can disperse a long way from the source.

The indoor environment

5.25. A great deal has been written about indoor air pollution and indoor aeroallergens. There are also numerous reports which examine the relationships between indoor air pollution and health and indoor aeroallergens and health but very little attention has been given to the inter-relationships and interaction between these two aspects. Very few integrated studies have been attempted and no detailed chemical analyses have been undertaken to investigate the influence of air pollutants on the structure of indoor allergens.

5.26. Despite the lack of background some general statements can be made. There is no reason to suppose that the interaction of air pollutants and aeroallergens should be less significant indoors than outdoors. Aeroallergens are typically present indoors for longer periods of the year than those of the outside atmosphere and in some cases are present all year round.

5.27. The enclosed atmospheres of buildings can allow allergens and pollutants to accumulate to high concentrations especially when ventilation rates are low. This is particularly relevant in highly insulated dwellings with low rates of air exchange. House dust mites and many types of fungi thrive

in humid environments, leading to high levels of contamination in the same locations. Studies have found that indoor mould concentrations do not vary much through the year although those in the outside air typically show a significant decrease in winter months [77]. In newer houses mould spore levels often increase in winter because of poor ventilation. Fungi can operate over a wide range of humidity levels but are particularly abundant in damp homes or on moist substrates in dry homes (e.g. window frames, stale food, clothes, wall paper). Some xerophytic fungi (i.e. those adapted to living in dry places), such as microfungi living in textiles and dust can grow at low relative humidities and will be present in virtually all houses [78, 79].

5.28. The increasing use of moulds in industrial processes such as the manufacture of antibiotics, enzymes and steroids, and in food production, including bread, wine and beer, is likely to increase sensitization in the population because of increasing exposure to high concentrations. This may lead to higher incidences of fungal allergy in the home.

5.29. Allergens from pets are likely to be present in higher concentrations during the winter months because of decreased ventilation. Work by Findlay [80] found that cat allergen could be carried on very small particles, capable of remaining airborne for long periods. This association of allergen on particles could be significant in air contaminated with tobacco smoke or fine dust, in a similar way to the adherence of proteins on DEP. Recent work by Wood *et al.* [81] on the aerodynamic characteristics of cat allergen found that a small but consistent fraction was bound on small particles but the majority was held on large particles. Contrary to other studies they concluded that neither allergen levels or particles size distribution was influenced by ventilation rates.

5.30. Air conditioning and humidifiers have been associated with high counts of bacteria and may contribute to poor air quality, but the relationships between this and indoor pollution have not been explored.

Temporal and spatial variations in aeroallergens and air pollutants

Long-term variations in the main allergenic pollen types

5.31. Significant changes have occurred in the concentrations of grass pollen in the U.K. during the last 30 years. Changes in farming practice and land use have resulted in a significant reduction in pollen counts in many regions. Overall the area of grassland in the U.K. has decreased markedly during the last three decades. For example the area of grassland decreased by 37% in south-east England during the period 1961–90 (HMSO Agricultural Statistics, June returns). The period from the 1960s to the 1970s also saw a change from hay-making to silage production whereby the grass is cut before it flowers. At the same time the seed mix changed from species which produce abundant pollen such as Cock's foot (*Dactylis glomerata*) to types which produce less pollen such as Rye grass (*Lolium perenne*). This change in the strength of the source area is reflected in the cumulative grass pollen catches over the past three decades. The severity of the grass pollen seasons in London area reduced markedly from the 1960s to the 1970s and then experienced a steady decline through the 1980s [82]. This trend is evident also in the data for the Derby area [83] but the decline is less marked in this case. In both the London area and the Midlands the trend of decreasing grass pollen counts has levelled out during the last few years, probably because of the influence of set aside and uncut verges. In some areas, such as South Wales, the area of grassland has not decreased notably over the last few decades.

5.32. Birch pollen is the most important aeroallergen from trees in Britain. Long-term records are available for Derby, London and Cardiff. Characteristically birch pollen data shows large fluctuations in annual cumulative counts and severity of seasons. This is partly because the genus has inherent reproductive rhythms which tend to have biennial cycles of pollen productivity. This natural variation is superimposed on that due to climatic variations. When the annual sums are amalgamated to 5-year means in order to overcome this short-term fluctuation, the records for Derby show a 3-fold increase during the period 1971 and 1990 [83] and those for London show a similar increase for the period 1961–1991 [84]. These patterns probably result from increased planting of birch as ornamental trees and from the natural increase in this genus because of succession on marginal land.

5.33. Some aeroallergens have been introduced recently or are becoming more important. For example the area of cultivation for oil seed rape has increased substantially over the last ten years and currently occupies about 444,800 hectares. Although this crop is insect pollinated about 10% of the pollen becomes airbourne. Considerable uncertainty exists about the allergenic status of oil seed rape pollen and associated VOCs from the plants [85, 86].

Seasonal and spatial variations

5.34. Aeroallergens and air pollutants are subject to many of the same controls on their patterns of concentration and dispersal but the locations of their sources and the times of their peak emissions are often different. The dispersal of both groups of atmospheric contaminants relies mostly on

conditions of air flow, especially wind speed, turbulence and stability, and they are both influenced by temperature, precipitation and topography. Consequently there are some circumstances in which there is a close synchronization of high concentrations of air pollution and aeroallergens and others in which these contaminants peak separately.

5.35. It is beyond the scope of this paper to provide a detailed account of regional variations in aeroallergen load but a broad overview may be given. On a regional basis pollen and spore levels vary in relation to local vegetation, climate and topography. Overall growing seasons are longest in the south and west, decreasing progressively northwards but the length of pollen seasons does not always conform to this pattern. Recent research [87] has shown that the lag times between the start of the grass pollen season in different parts of the U.K. can vary annually from a few days to several weeks, and that the duration of the seasons may not always correspond with geographical location. A generalized pollen calendar is given in Table 5.1 to show the main flowering periods in Britain. This can vary by several weeks each year depending on the weather during the preseason period and at the time of anthesis.

5.36. Cumulative grass pollen counts for various parts of the U.K. reflect differences in source strengths with the highest occurring in areas with large amounts of grassland such as South Wales, the Midlands and central southern England and the lowest occurring in coastal areas and places with moorland vegetation. In nearly all cases concentrations of aeroallergens are much higher in rural areas than in towns and cities. For instance many fungi are plant pathogens or saprophytes and typically reach their highest abundance in agricultural areas. Similarly grass pollen concentrations in large urban areas are generally only 50% of those in the surrounding countryside. There are some exceptions to this pattern, for example tree pollen concentrations can be high in built-up areas if there are tree-lined streets or parks.

Table 5.1. Generalized pollen calendar for the U.K. (NB These taxa may include several species per group. This calendar is intended to be indicative only.)

Corylus (Hazel)	late Jan to mid March
Ulmus (Elm)	mid Feb to early May
Alnus (Alder)	early Feb to late April
Fraxinus (Poplar)	early to late April
Betula (Birch)	early April to mid May
Quercus (Oak)	late April to mid June
Fagus (Beech)	early to mid May
Planatus (Plane)	early to late May
Plantago (Plantain)	early May to mid Sept
Rumex (Dock)	mid May to mid July
Gramineae (Grasses)	late May to mid August
Urtica (Nettle)	late May to late Sept
Sambucus (Elder)	early June to mid July
Tilia (Lime)	mid June to mid July
Castanea (Sweet Chestnut)	late June to late July
Artemisia (Mugwort)	late July to late Sept
Fungal spores	All year but mostly July to late Oct

5.37. The temporal patterns in abundance of most fungal spores contrast with that for tree pollen types. Many allergenic fungi are most prolific in late summer and autumn but some are associated with damp weather after heavy rainfall in the summer or are prolific on warm, dry days [88, 89].

5.38. Considering the variation of aeroallergens in relation to air pollution there is clearly a spatial separation of their peak occurrences into urban and rural environments. The main exception to this is ozone which typically occurs in highest concentrations in rural areas downwind from cities. The photochemical pollutants peak under the same weather conditions that are conducive for peak pollen counts. Examination of the data from the 12 European Aeroallergen network sites in the U.K. (Pollen Research Unit, unpublished data) has shown that during June and July there is a close synchronization between peaks of pollen and NO_x and/or O_3 on warm, sunny days with slow to moderate air flow. High concentrations of NO_x and O_3 may feature through the rest of the summer before and after the main pollen season. Airborne allergen may still be present during this time. In urban areas nitrogen dioxide concentrations may be high throughout the year. Although SO_2 concentrations are relatively low during the summer months at most of the 12 sites, trends in daily variations tended to follow the same general patterns as the pollen counts. These temporal coincidences of aeroallergens and air pollutants are important for both aerobiology and allergy. Further research is needed to investigate the inter-relationships both in urban and rural environments.

Summary

5.39. Little attention has been paid to interactions between aeroallergens and air pollutants but several aspects of this topic are critical to understanding the role of air pollution in allergic disease. Air pollution can effect the abundance of aeroallergens from plants indirectly by reducing productivity. This may lead to a reduction in both the amount of pollen formed on the plants and in the size of the pollen grains. Exposure to air pollutants can influence pollen viability. Certain pollutants, including SO_2, NO_x and O_3 may alter the allergenic proteins of pollen grains, most significantly by increasing the amount of free

amino acids. The existence of micronic and submicronic allergen bearing particles has been demonstrated clearly during the last ten years but little is known about their chemistry or origins. Some are thought to be derived from pollen whilst others may emanate from other plant materials. This size fraction is important because it is respirable and may react with pollution particles in the atmosphere.

5.40. Volatile organic compounds (VOCs), such as those released by oilseed rape plants, may have a role in causing allergic reactions but current work suggests that they are mostly irritants rather than allergens. Interactions between VOCs and pollutants may be important in some circumstances, for example locally in rural areas where ozone concentrations can be high. Very little work has been done on interactions between fungal spores and air pollutants although fungi are likely to be present in polluted atmospheres since they grow in virtually every habitat both indoors and out. Very few studies have investigated the influence of air pollutants on the structure of indoor aeroallergens but there is no reason to suppose that the interaction of air pollution and aeroallergens should be less significant indoors than out.

5.41. The characteristics of the pollution load and the abundance of some of the most important aeroallergens have changed in the U.K. over the last few decades. Concentrations of grass pollen have decreased markedly in many regions, such as the south east, during the last 30 years but in some areas, including South Wales, the amount of grassland has not changed notably. The abundance of some of the other most important allergenic pollen types has remained about the same or has increased slightly. The acreage of some crops such as oil seed rape has increased substantially in the last ten years. Uncertainty exists about the allergenicity of the pollen and the VOCs from this crop.

5.42. Aeroallergens and air pollutants share many of the same controls on their patterns of concentrations and dispersal but the location of their sources and the times of their emissions are often different. Sometimes there is a close synchronization of peaks in air pollution and aeroallergens for example in mid summer with ozone and pollen in rural areas. Exposure to aeroallergens varies a great deal regionally over the U.K. Generally pollen seasons are longest in the south and west and are most severe in areas with prolific meadow grasses such as the south east, South Wales and the Midlands. Areas of priority for future research include the sources and chemistry of micronic and submicronic allergen-bearing particles, the detailed effects of pollutants on pollen grain proteins and interactions between VOCs and air pollutants.

Future research priorities

5.43. The discussion in this section has highlighted the need for more research on aeroallergens and air pollution. The interdisciplinary nature of the topic has resulted in the relevant publications which have been produced to date being dispersed in various journals covering a diverse spectrum of subjects including horticulture, botany, plant physiology, forestry, air pollution, aerobiology and allergy. Research hitherto has been fragmented and has not tackled some of the key issues relevant to allergic disease. In particular the following areas of future research should be regarded as priority in this context:

(a) the detailed effects of air pollutants on the structure and allergenicity of pollen proteins;
(b) the origins and abundance of micronic and submicronic allergen bearing particles in relation to the spatial and temporal distribution of air pollutants. The chemistry of the interactions of these particles with air pollutants in the ambient atmosphere;
(c) the influence of air pollution on pollen production and the sizes of grains;
(d) the role of VOCs in allergic disease and their interaction with air pollutants;
(e) the spatial and temporal distribution of allergens in the ambient atmosphere in relation to air pollutants;
(f) relationship between aeroallergens and air pollutants in the indoor environment.

Many of these research topics would have relevance to other disciplines besides allergy, including horticulture, agriculture and forestry.