

7.6 Aeroallergens

The prevalence of hay fever and asthma, including forms known to be triggered by aeroallergens, is on the rise worldwide (Schmidt, 2016). The risk of respiratory diseases associated with aeroallergens (as well as ozone) is projected to increase in the future (Pörtner et al., 2022). Aeroallergens are airborne substances such as pollen, dust mites, or spores from molds that trigger allergic reactions in sensitized individuals. Most aeroallergens come from trees, weeds, and grasses that rely on wind to distribute their pollen or spores.

A growing number of experimental and field studies provide compelling evidence that warming temperatures and changing patterns of precipitation, along with increasing carbon dioxide (CO₂) levels, are increasing plant growth and pollen production. Climate-related changes include pollen yields, pollen season timing and length, and allergen content of pollen grains (Anderegg et al., 2021; Anenberg et al., 2017; Ray and Ming, 2020; USGCRP, 2018; Zhang and Steiner, 2022; Ziska et al., 2019). Elevated CO₂ concentrations have also been experimentally shown to amplify allergenic mold spore production from leaves of timothy grass, a common livestock feed (Wolf et al., 2010).

Heavy short-term rainfall can significantly reduce atmospheric pollen concentrations by wet deposition while changes in long-term precipitation patterns enhance or inhibit plant growth and alter total pollen production (Zhang and Steiner, 2022). Thunderstorms, which have become more frequent with warming ocean temperatures, have also been linked to increases in aeroallergen levels. Thunderstorms during the pollen season have been reported to trigger severe asthmatic symptoms in people with underlying asthma, hay fever, and allergic rhinitis (D'Amato et al., 2020; Ray and Ming, 2020). Scientists have hypothesized that during rainy storms, pollen grains are broken up into smaller allergenic particles that can induce severe asthma. There is also evidence that thunderstorms increase atmospheric mold and fungal spore concentrations and contribute to asthma-related hospital emergency visits (D'Amato et al., 2020; Domingo et al., 2024).

Pollen seasons are already increasing in length and intensity, and are expected to increase further as the climate warms (Nolte et al., 2018). Over the last several



decades, warmer temperatures have driven pollen season start dates for spring-flowering plants (e.g., deciduous trees) to advance by 3 to 22 days, while late-flowering plants (e.g., grasses) have delayed pollen season start dates by up to 27 days (Zhang and Steiner, 2022). Since 1995, the ragweed pollen season has lengthened by more than 20 days in parts of the northern United States, with the largest increases observed at higher latitudes in the north-central region (Rudolph et al., 2018). Eleven locations across North America, Europe, and Asia showed a significant increase in pollen season duration over a 20-year period, with an average of 0.9 additional days per year (Ziska et al., 2019). Pollen records from 1990-2018 at 60 stations across North America, including Fresno, Los Angeles, Sacramento, San Diego, and San Francisco, show an approximately 20-day advance and 8-day lengthening of the pollen season (Anderegg et al., 2021). Climate model simulations suggest that human-caused climate change was the dominant driver of recent increases in pollen season length and contributed to increases in pollen concentrations, particularly from 2003 to 2018. In addition to influencing pollen production and seasonality, climate change affects respiratory health through other pathways, including more frequent and intense extreme heat events. Adults in the United States who were most exposed to extreme heat from 1997 to 2013 had a higher likelihood of hay fever compared to those with the lowest exposure, especially when exposure occurred during the spring (Upperman et al., 2017).

In addition, dust mites and mold thrive in warmer, more humid conditions which are expanding globally due to climate change; hydrological disasters such as flooding and intense storms also increase indoor humidity which promotes dust mite, mold, and fungal growth (Beggs et al., 2023; Domingo et al., 2024; Seidel et al., 2024). One study of the San Francisco Bay Area found that the annual duration of mold spore exposure increased by an average of 0.51 weeks per year between 2002 and 2019, based on the number of weeks in which mold spores are detected (Paudel et al., 2021). Climate change is also linked to increased concentrations of air pollutants such as ozone, nitric oxide, and other volatile organic chemicals which may also be partially responsible for the increase in allergic respiratory disease reported over the past several decades (Ray and Ming, 2020). Large wildfires, which are becoming more frequent in California, can increase fungal outbreaks and dispersal (Seidel et al., 2024).



Populations that may experience greater health impacts associated with a spread of aeroallergen exposure include children and infants, the elderly, and people with fewer resources to manage these impacts. People with lower incomes and some racial/ethnic groups, including African Americans and residents of historically redlined and under-resourced areas in the US, many of which are predominantly Black and experience higher rates of asthma, asthma exacerbation rates, asthma-related emergency visits, and worse asthma outcomes (Domingo et al., 2024). Despite the relevance of seasonal allergies to public health and climate change, spatiotemporal patterns of seasonal allergies are poorly understood. Most cases are mild and go unrecorded, and as a result, medical records often fail to capture how seasonal allergies change across regions and over time. In addition, aeroallergen measurements are sparse, geographically limited, and often restricted to pollen—particularly in the United States. Internet-based surveillance could be used to track seasonal allergies (Stallard-Olivera and Fierer, 2024), although long-term monitoring in California is needed to assess how allergies are responding to climate change.

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