Implications of Climate Change for Pollen and Allergic Diseases

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Allergic Disease: Setting the Stage

- Complex set of diseases influenced by genetics, allergens, and other environmental exposures

- Asthma:
  - 8% of adults and 10% of children in the US
  - $56 billion in medical expenditures, missed work and school days, and early deaths in the US in 2007

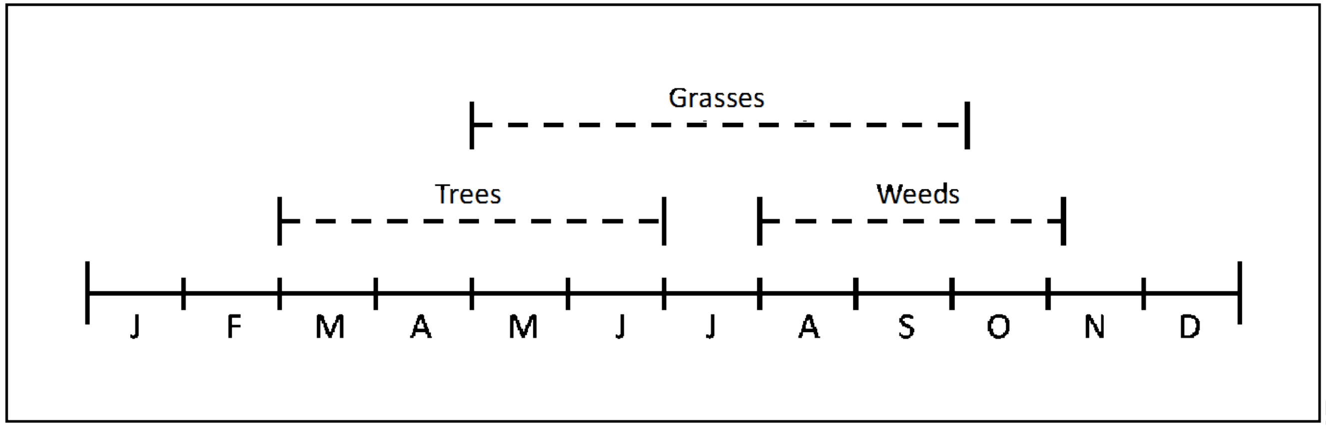
- Allergic rhinitis or “hay fever”
  - 7.5% of adults and 9% of children in the US 2012
  - $11.2 billion in health services and prescription medication sales in the US in 2005

CDC 2011, Kelly et al. 2016, Blackwell et al. 2014, Bloom et al. 2013, Soni 2008

Pollen Allergens

- Many types of pollen are known allergens

- Broadly categorized as tree, grass, or weed pollen



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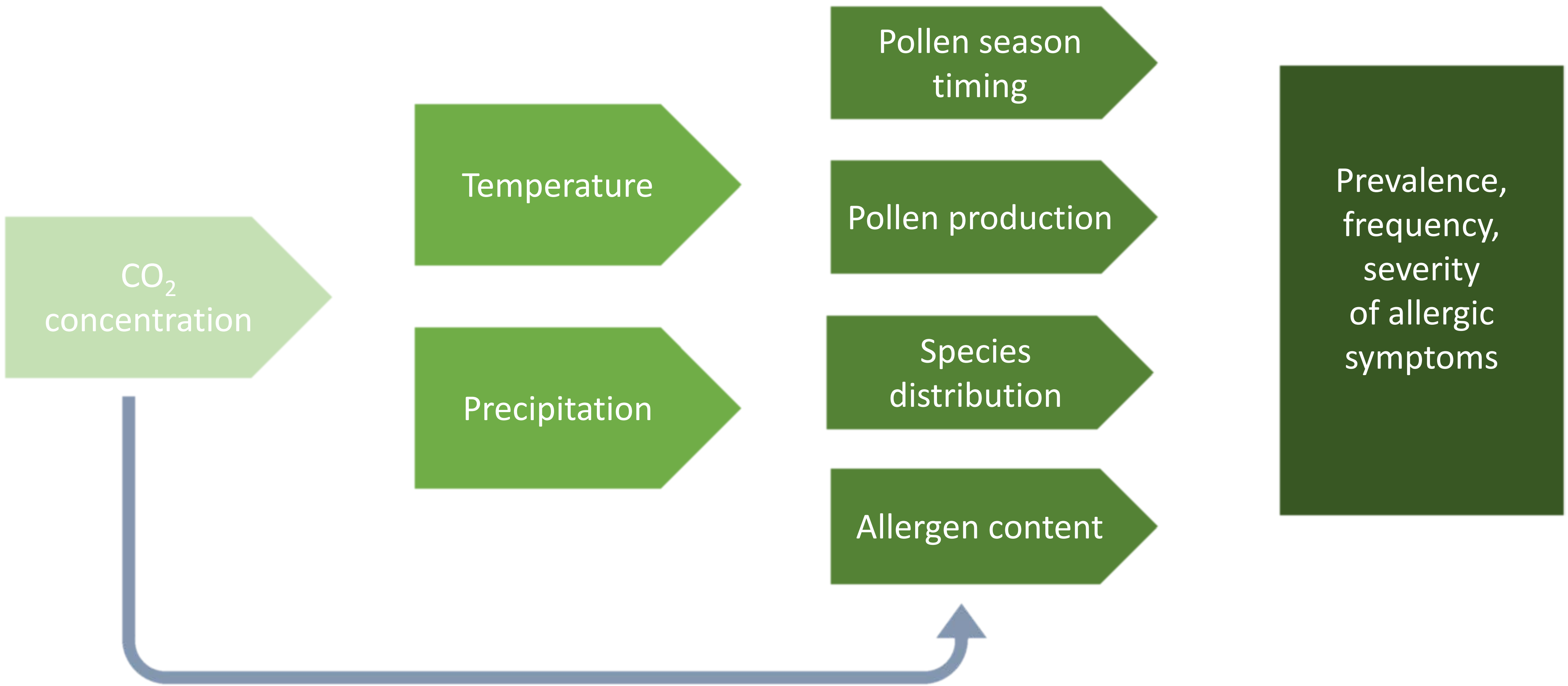
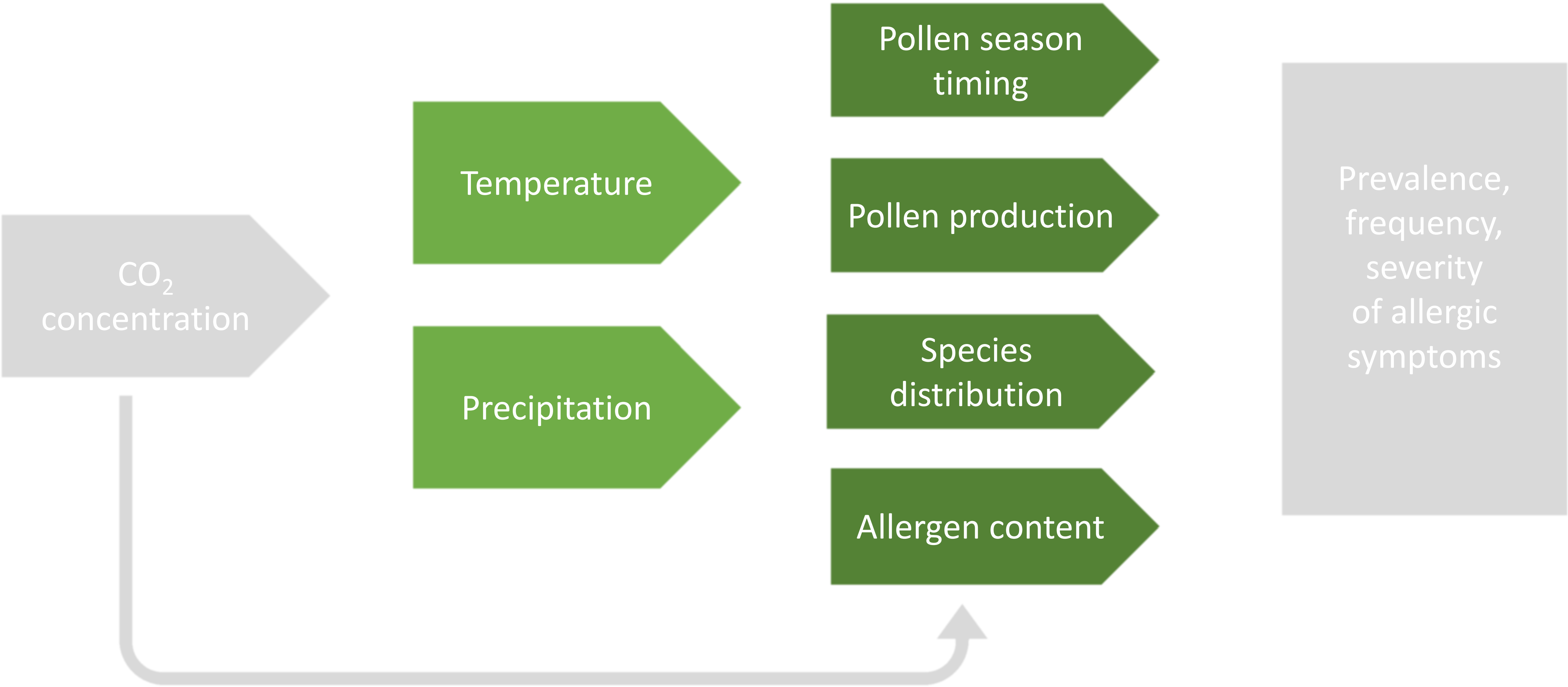
Potential Pathways



Adapted from: Sheffield et al. *MSJM* 2011

Potential Pathways



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Advance of Pollen Season Start Date

- Many studies find:
  - Start date (i.e., days since January 1st) correlated with temperature in months prior to season
  - Advance of start date over the last ~ 30 years, consistent with increases in temperature

Season Start Date, 1981-2007, Liguria, Italy

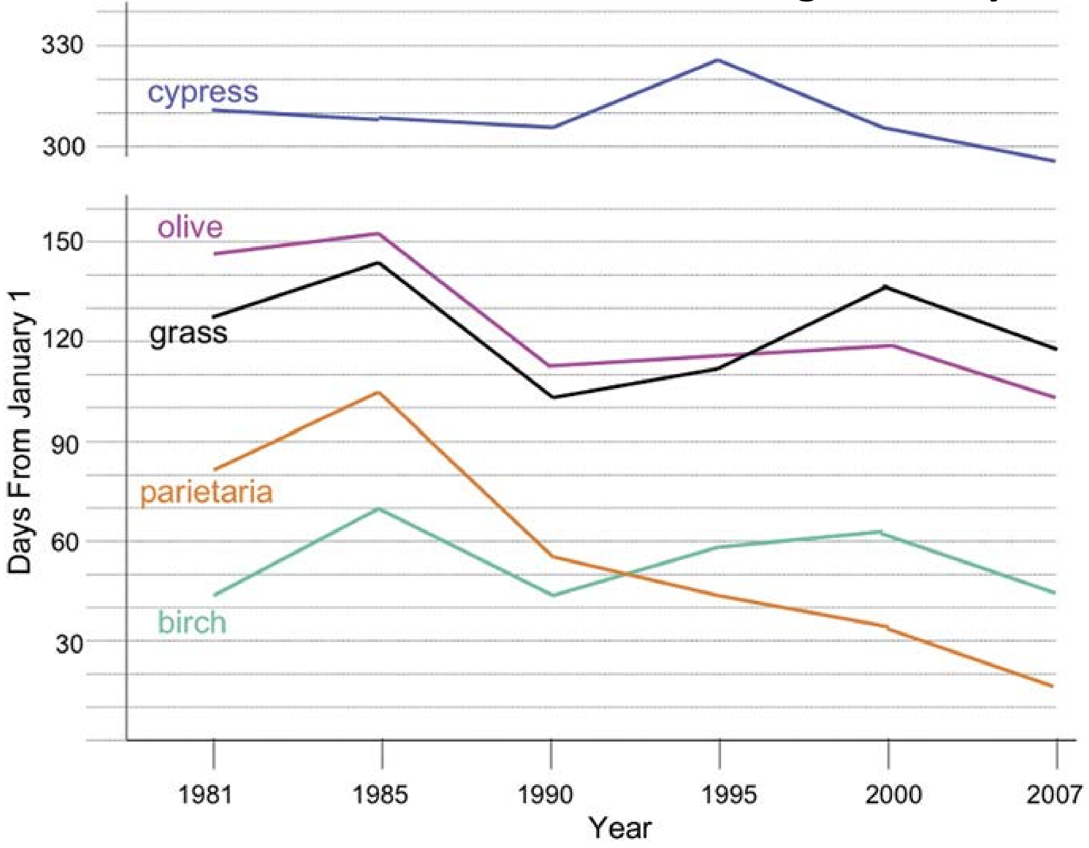


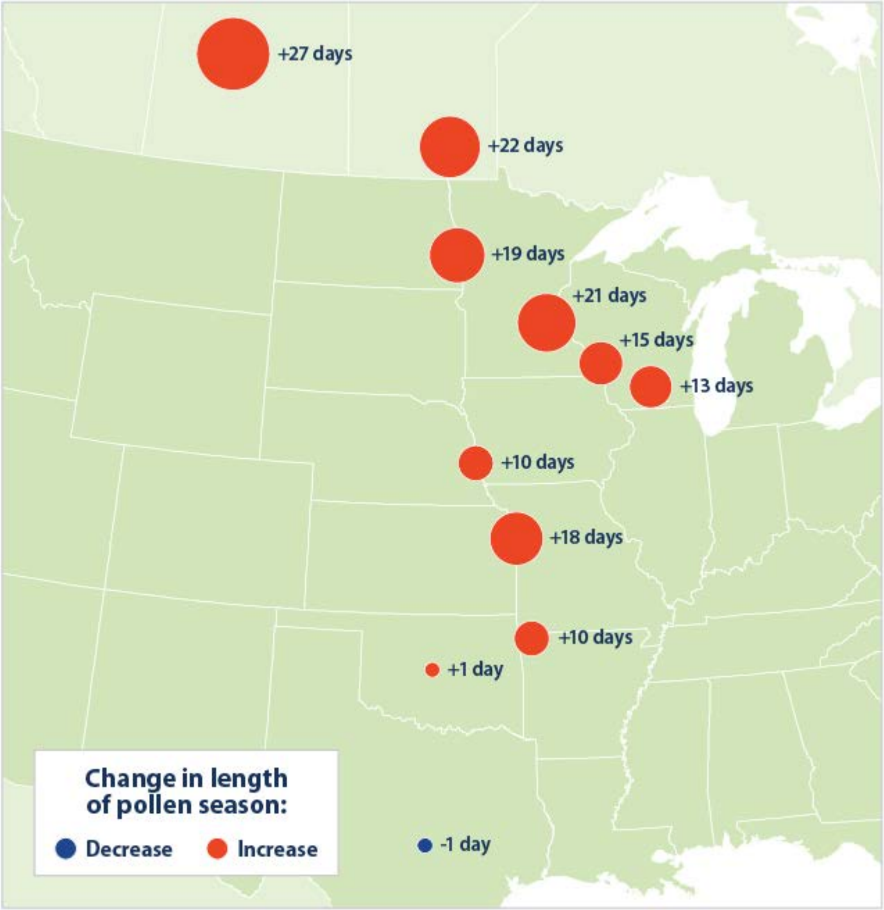
Figure 1. Start date (day of the year from January 1) of the pollen seasons of the 5 plants throughout the study years.

Ariano et al. *Ann Allergy Asthma Immunol* 2010, 104: 215-222

Increase in Pollen Season Length

- Length of the pollen season increases in response to warmer temperatures
- More days of pollen exposure per year
- Strongest evidence comes from species flowering in summer or later (e.g., ragweed)

Ragweed Pollen Season Length, 1995-2013



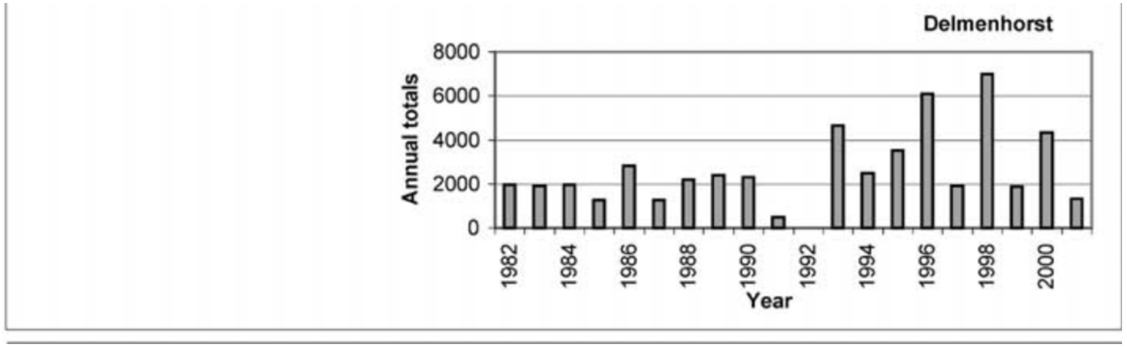
Data from Ziska et al. *PNAS* 2011

Increase in Pollen Production

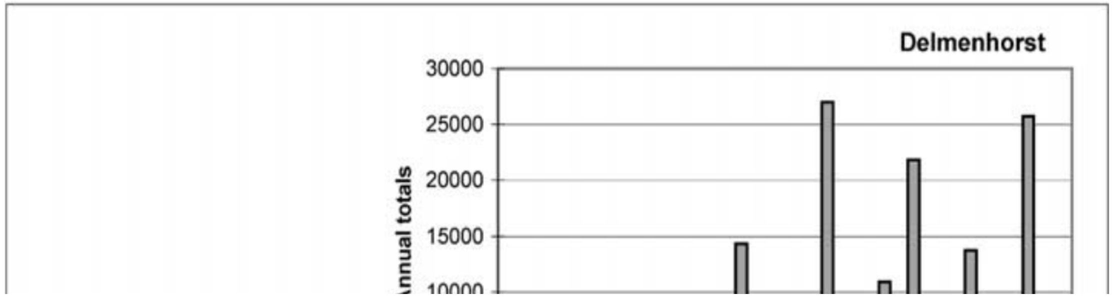
- Increased temperature and precipitation in the months prior to the pollen season leads to higher pollen production in some species

- Higher pollen exposures

Oak Annual Totals, 1969-2001



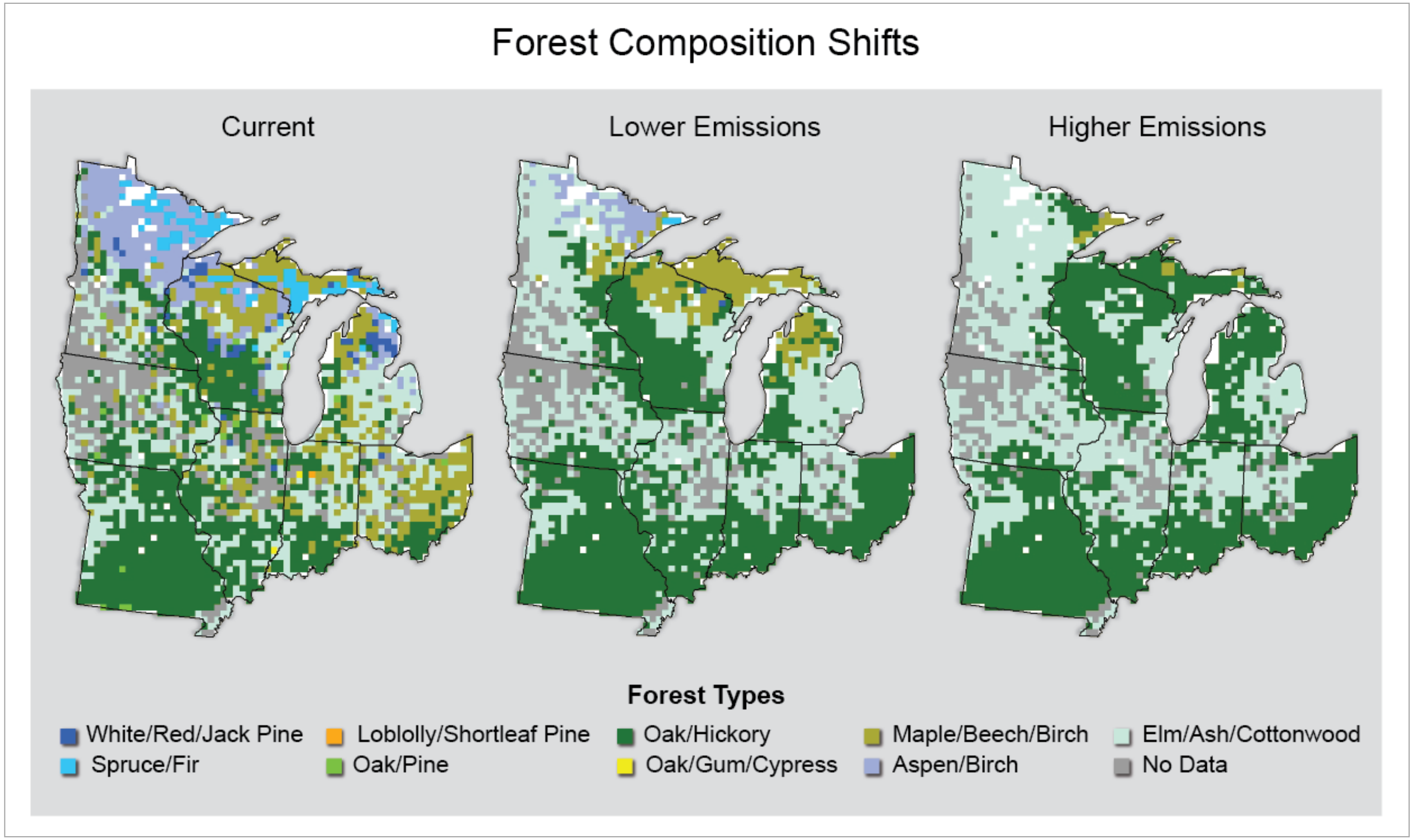
Birch Annual Totals, 1969-2001



Spieksma et al. Aerobiologia 2003; Cecchi et al. *Allergy* 2010

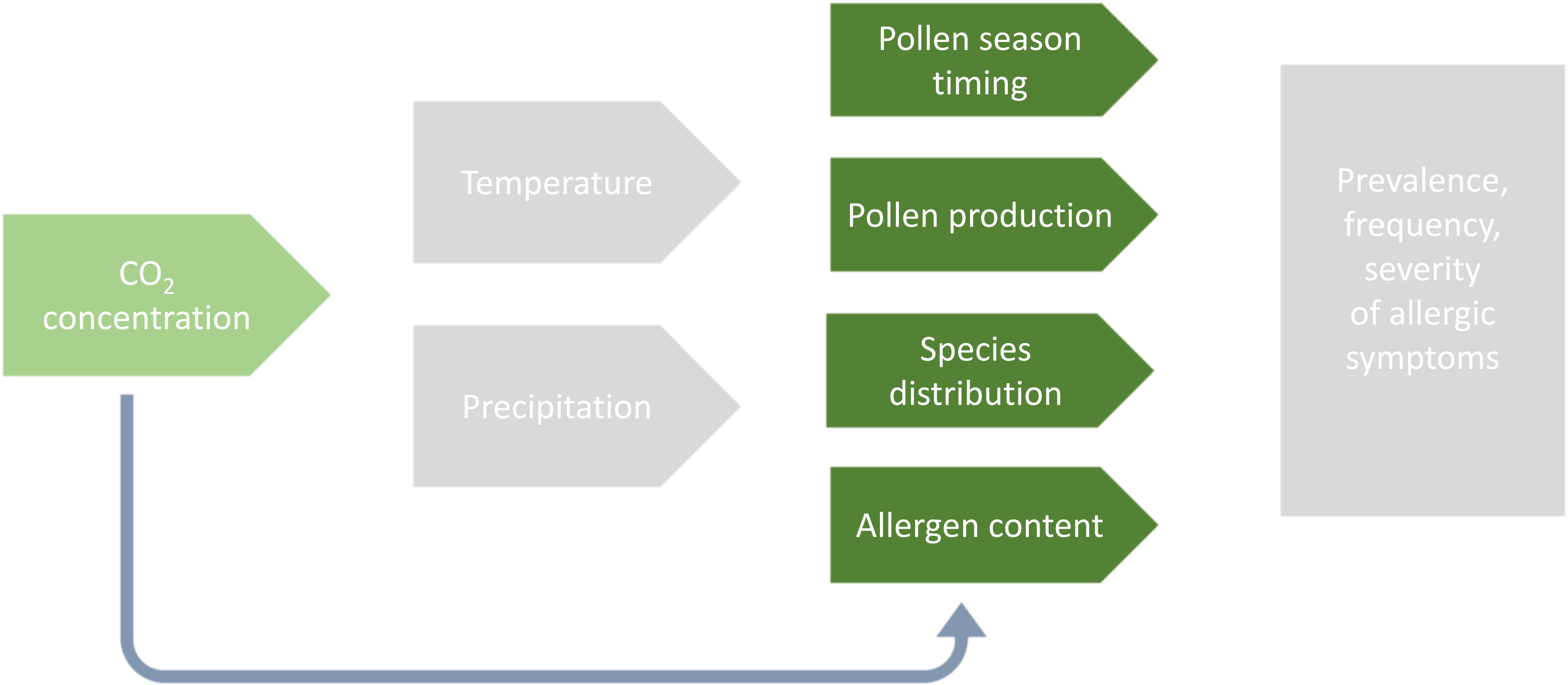
Shifts in Species Distribution

Climate change is likely to alter the geographic distribution of allergenic plants over long periods of time (i.e., decades)



Prasad et al. 2007: A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]

Potential Pathways



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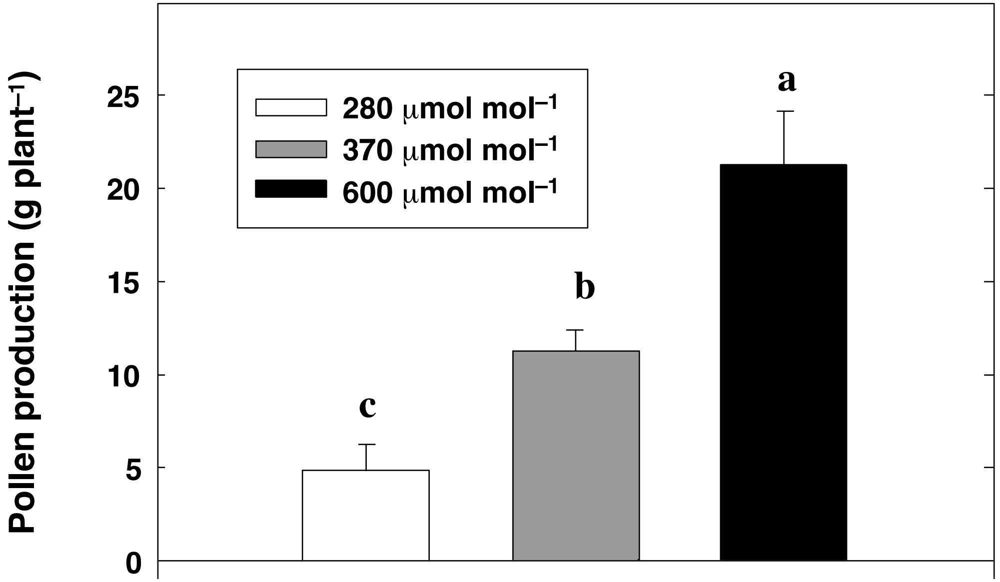
Ragweed Pollen Production as a Function of CO_2



280 ppm: Preindustrial
370 ppm: Time of study
600 ppm: Projection for 2050

Photo credit: Guy Robinson (Fordham University)

Ziska et al. *Aust J Plant Physiol* 2000

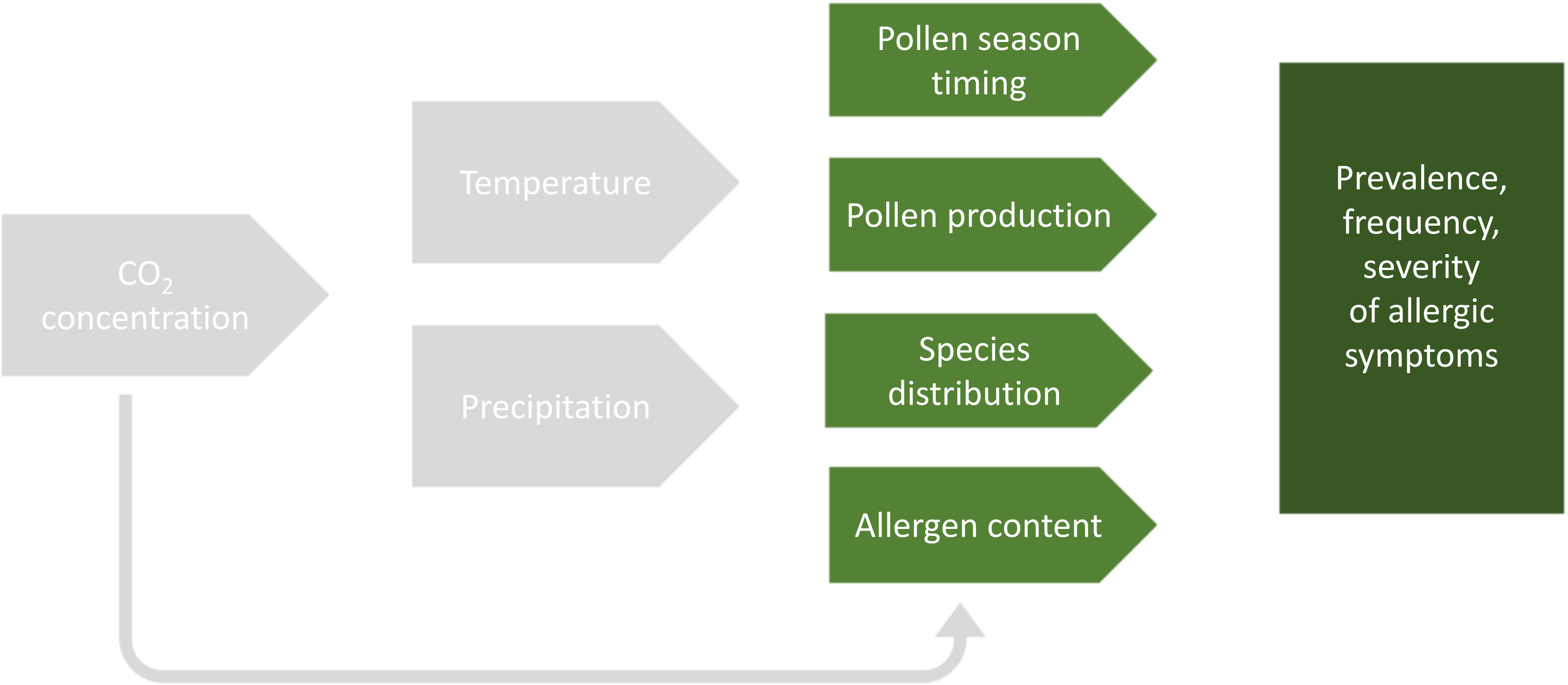
Ragweed Allergen Content as a Function of CO_2

$[CO_2]$ (μmol mol^{-1})	Protein concentration (μg mg^{-1} pollen)	Amb a 1 concentration (ELISA mg^{-1} protein)	Amb a 1 concentration (ELISA mg^{-1} pollen)
280	21 ± 2	4490 ± 960^{A}	93 ± 20^{A}
370	20 ± 2	5290 ± 560^{B}	103 ± 11^{B}
600	22 ± 2	8180 ± 900	178 ± 20

$^{A}P<0.005$ when compared with projected 21st century $[CO_2]$, *t*-test using unequal variances.
$^{B}P<0.01$ when compared with projected 21st century $[CO_2]$, *t*-test using unequal variances.

Singer et al. *Functional Plant Biology* 2005

Potential Pathways



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Development of Allergic Disease

Allergen exposure

↓

Allergic sensitization
(IgE to allergen)

Allergic rhinitis

↓

Exacerbation
(nasal congestion, runny nose, itching, sneezing)

Allergic asthma

↓

Exacerbation
(wheezing, difficulty breathing, coughing, chest tightness)

Pollen Exposure and Allergic Disease

- Exposure to pollen is associated with:
  - Development of allergic sensitization
  - Exacerbation of allergic asthma
  - Exacerbation of allergic rhinitis

- Higher pollen exposures could lead to:
  - Increased prevalence of allergic sensitization
  - More frequent and severe symptoms

- Population-level studies suggest most important pollen types differ by region

Pollen and Asthma ED Visits – Atlanta

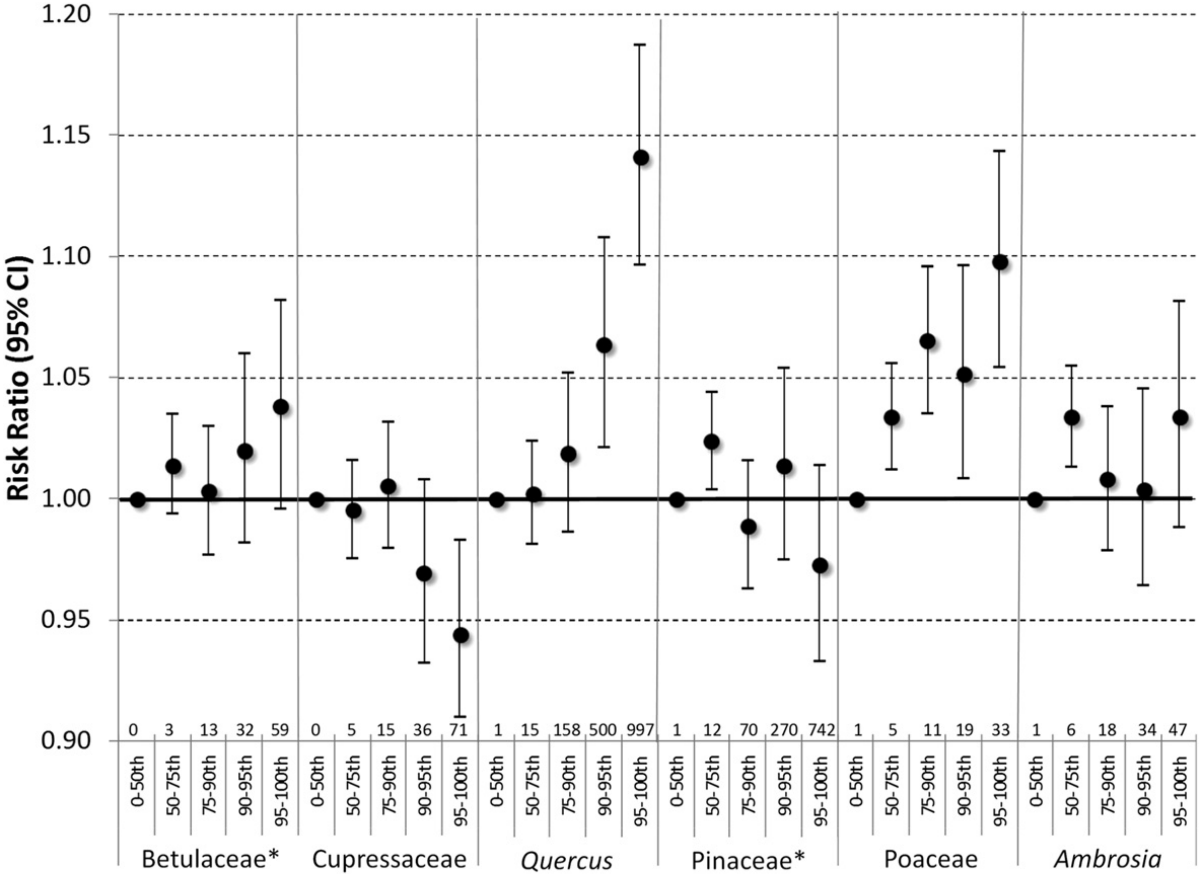
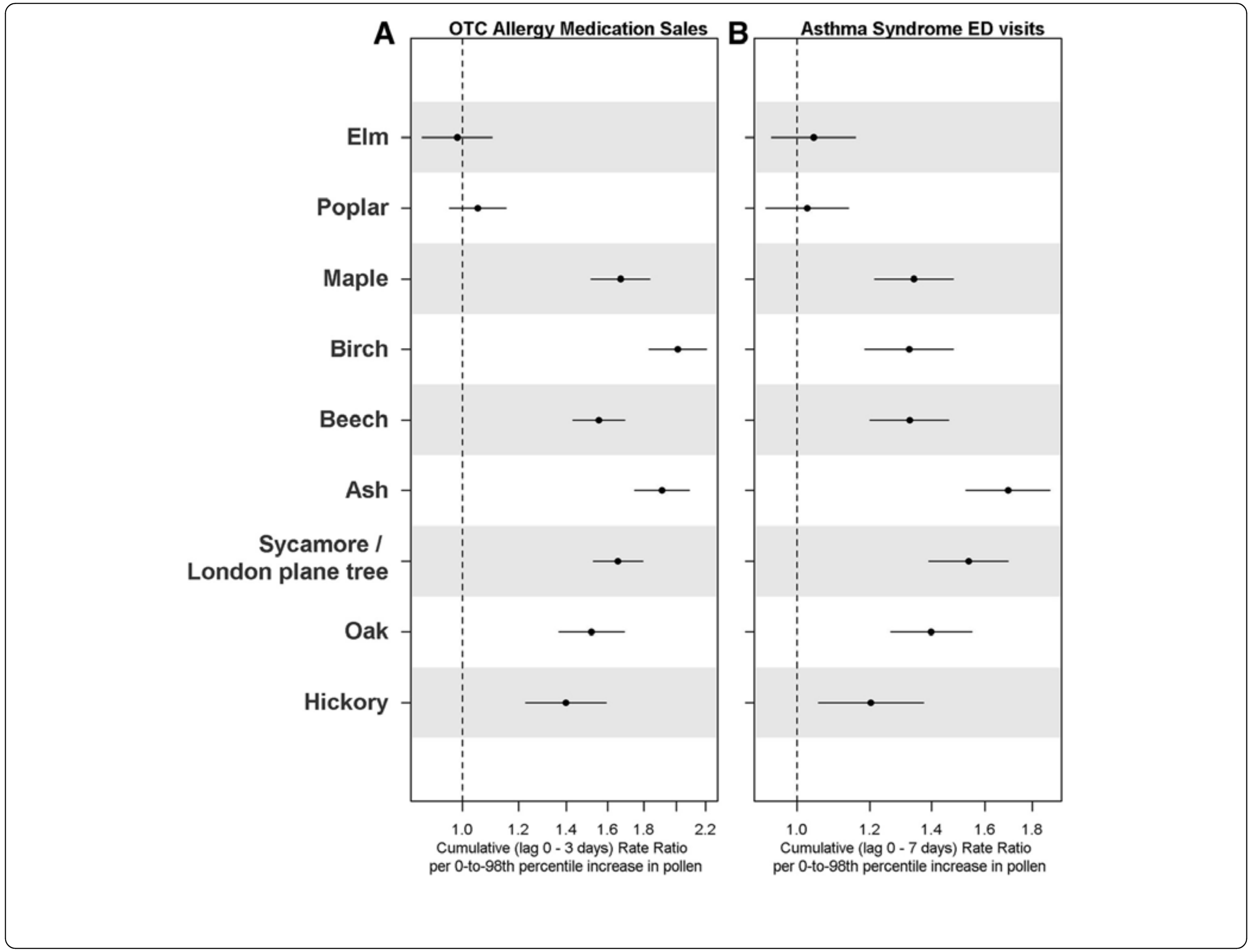


FIG 3. Risk ratios and 95% CIs for categories of 3-day moving average pollen levels. Numbers above the *x-axis* indicate median pollen concentrations for each category. *Risk ratios for Betulaceae and Pinaceae are controlled for *Quercus* species concentrations.

Daily concentrations of grass and oak pollen associated with increased asthma ED visits

Darrow et al. *JACI* 2012

ED Visits and Medication Sales – NYC



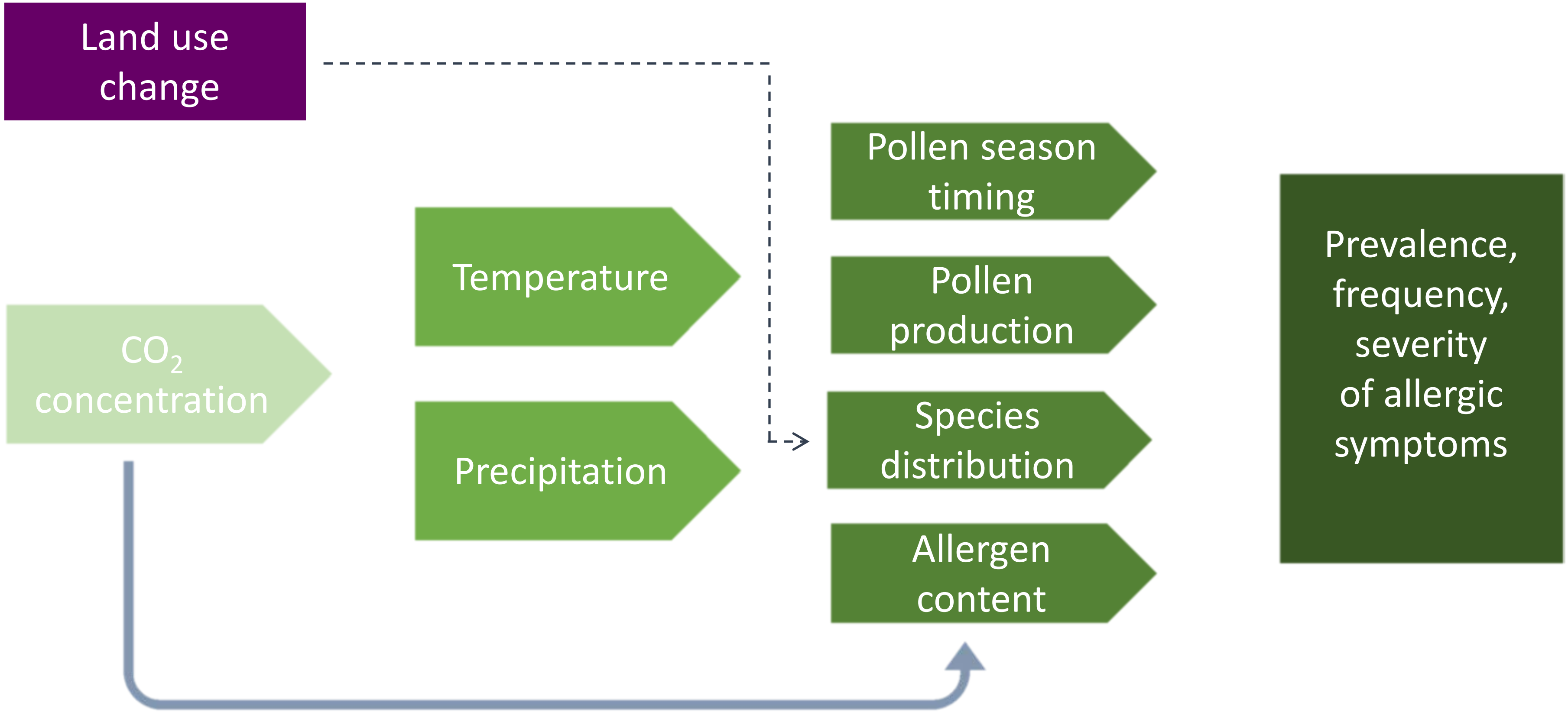
Asthma ED visits and over-the-counter sales of anti-allergy medications associated with spring tree pollen

Strongest associations:

- Ash
- Sycamore
- Birch

Ito et al. *Environ Health* 2015

Potential Pathways



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Sources of Uncertainty: Land Use

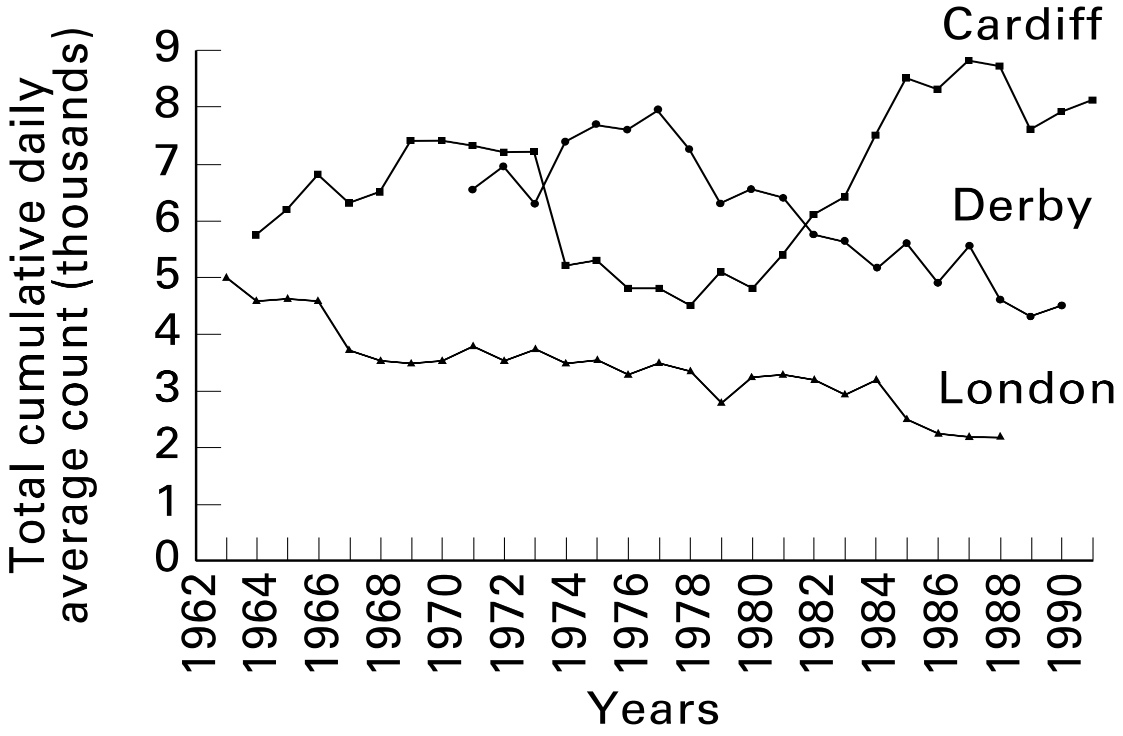
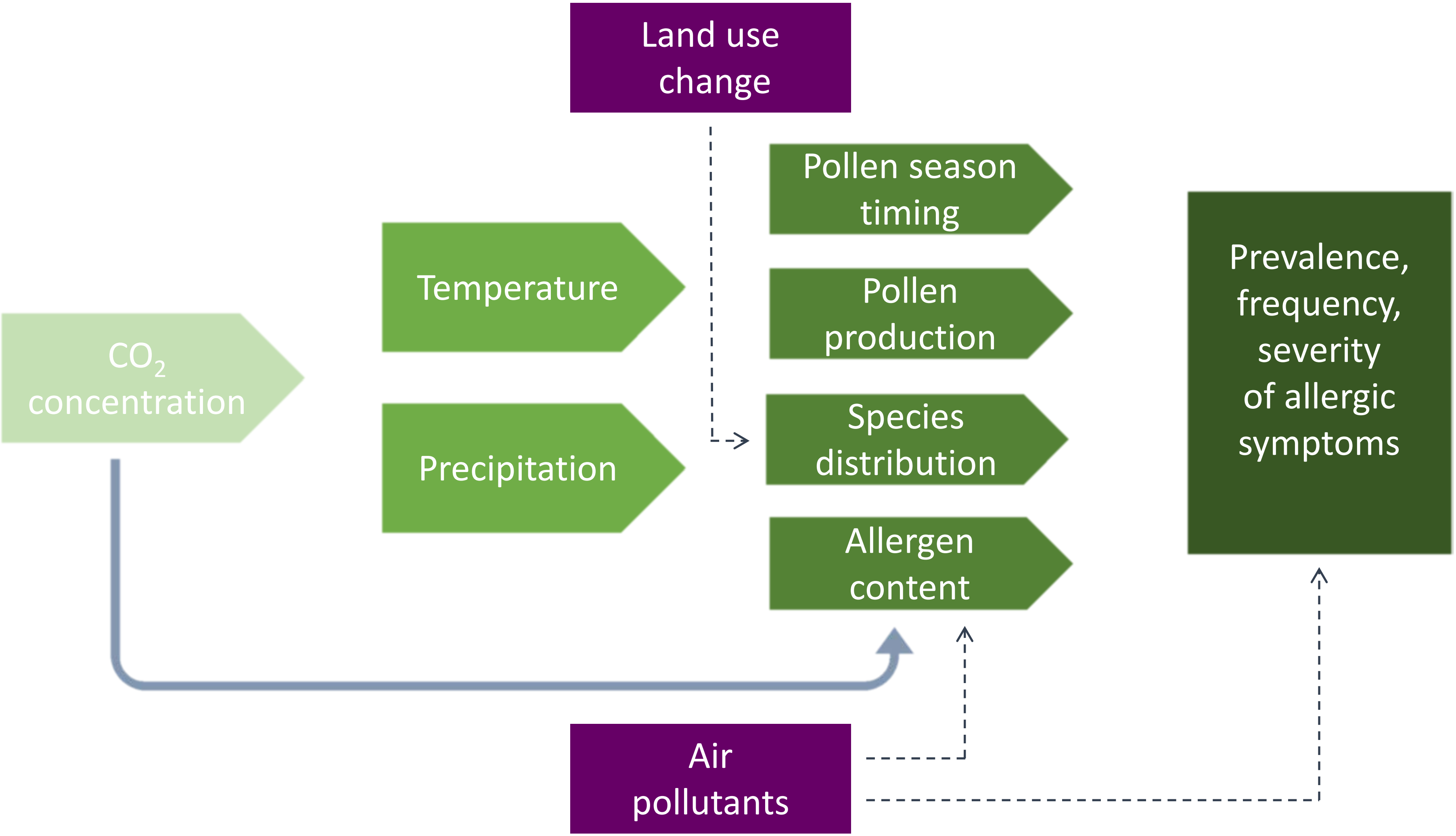


Fig. 1. Five year running means of cumulative yearly grass pollen counts.

Decline in grass pollen totals at two sites in the UK linked to decrease in grassland within 40 km

Emberlin et al. *Clin Exp Allergy* 1999

Potential Pathways



Adapted from: Sheffield et al. *MSJM* 2011

Sources of Uncertainty: Air Pollutants

- Altered expression of allergenic proteins within pollen grains - e.g., for ozone:
  - ↑ expression of the birch allergen Bet v 1
  - ↓ expression of the grass allergen Phl p 5

- Ozone, $PM_{2.5}$, and sulfur dioxide exposure leads to increased permeability of mucous membranes, enhancing allergen interaction with immune system cells

- Diesel exhaust particles may facilitating the process of sensitization to allergen

Beck et al. *PLOS One* 2013; Albertine et al. *PLOS One* 2014; D'Amato &Cecchi. *Clin Exp Allergy* 2008; Shea et al. *JACI* 2008

Summary

- Temperature, precipitation, and CO_2 influence multiple aspects of the pollen season

- Future changes in these factors due to climate change could lead to longer and more intense periods of pollen exposure, which in turn could increase the prevalence and severity of allergic disease

- Magnitude of change will likely vary by region due to:
  - Trends in land use and air pollution
  - Differences in regional climate
  - Differences in pollen types across regions
  - The degree to which different pollen types are influenced by climate
  - Regional variation in the dominant pollen types driving allergic disease
  - Mitigation and adaptation strategies