Plant of the Day

https://www.youtube.com/watch?v=7cBD73o4oGE

Selaginella lepidophylla (aka Resurrection plant, false rose of Jericho)

Species of desert plant in the spikemoss family (lycophytes evolved 400 million years ago and lack true leaves and roots)

Sold as a novelty plant

Selaginella moellendorffii genome sequenced (smallest plant genome yet 127Mbp)

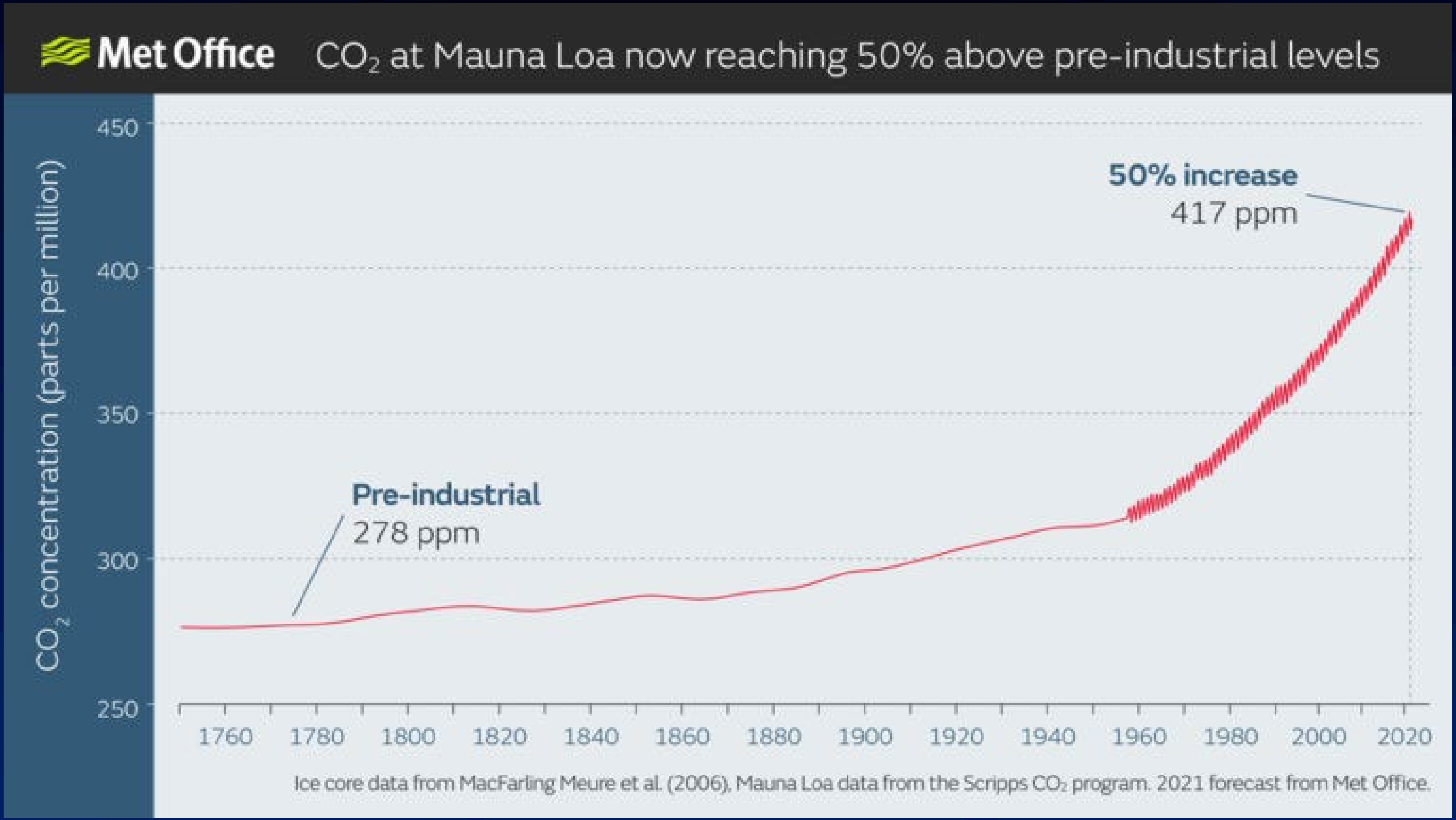
Used to identify genes for drought tolerance for use in crops

Plant Evolution and Climate change – Biq Questions

The global selection experiment

How will species, populations and communities respond to climate change?
Can plants adapt or migrate fast enough to avoid extinction?
How can we minimize extinction due to climate change?

CO_2 The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 278 ppm to 417 ppm in 2020



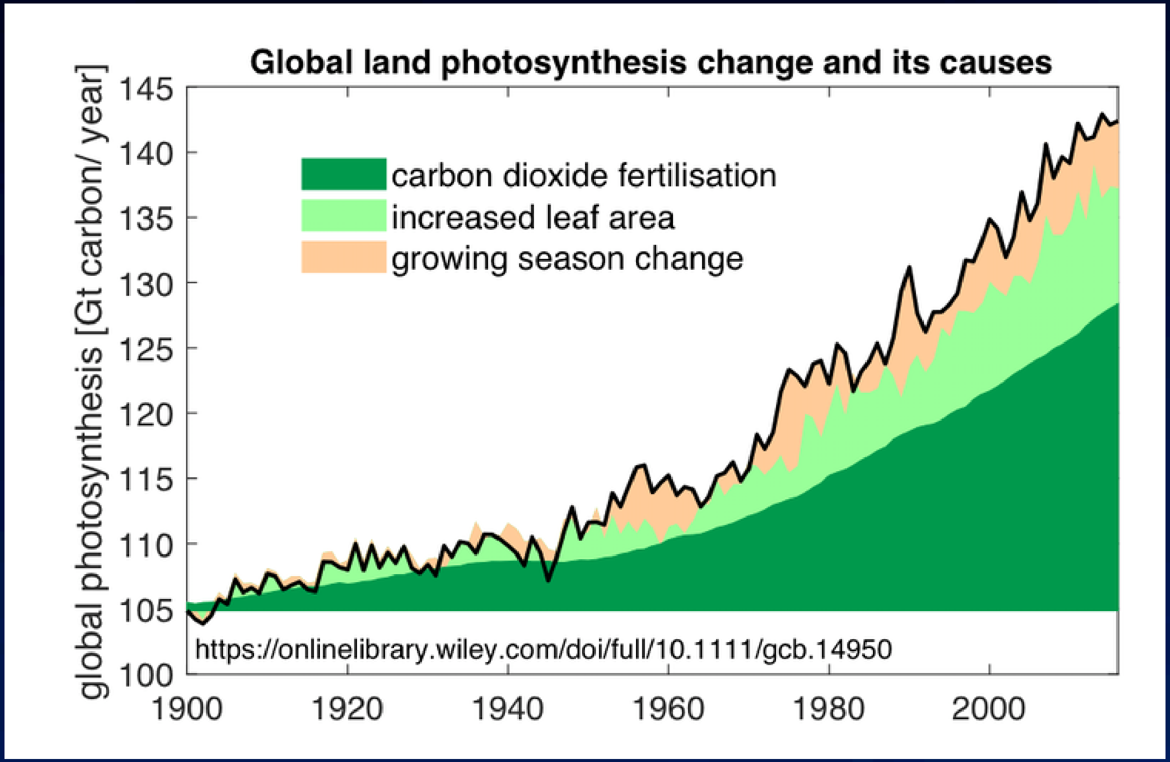
Methane and nitrous oxide show similar trends

Wide-ranging effects of increased CO_2

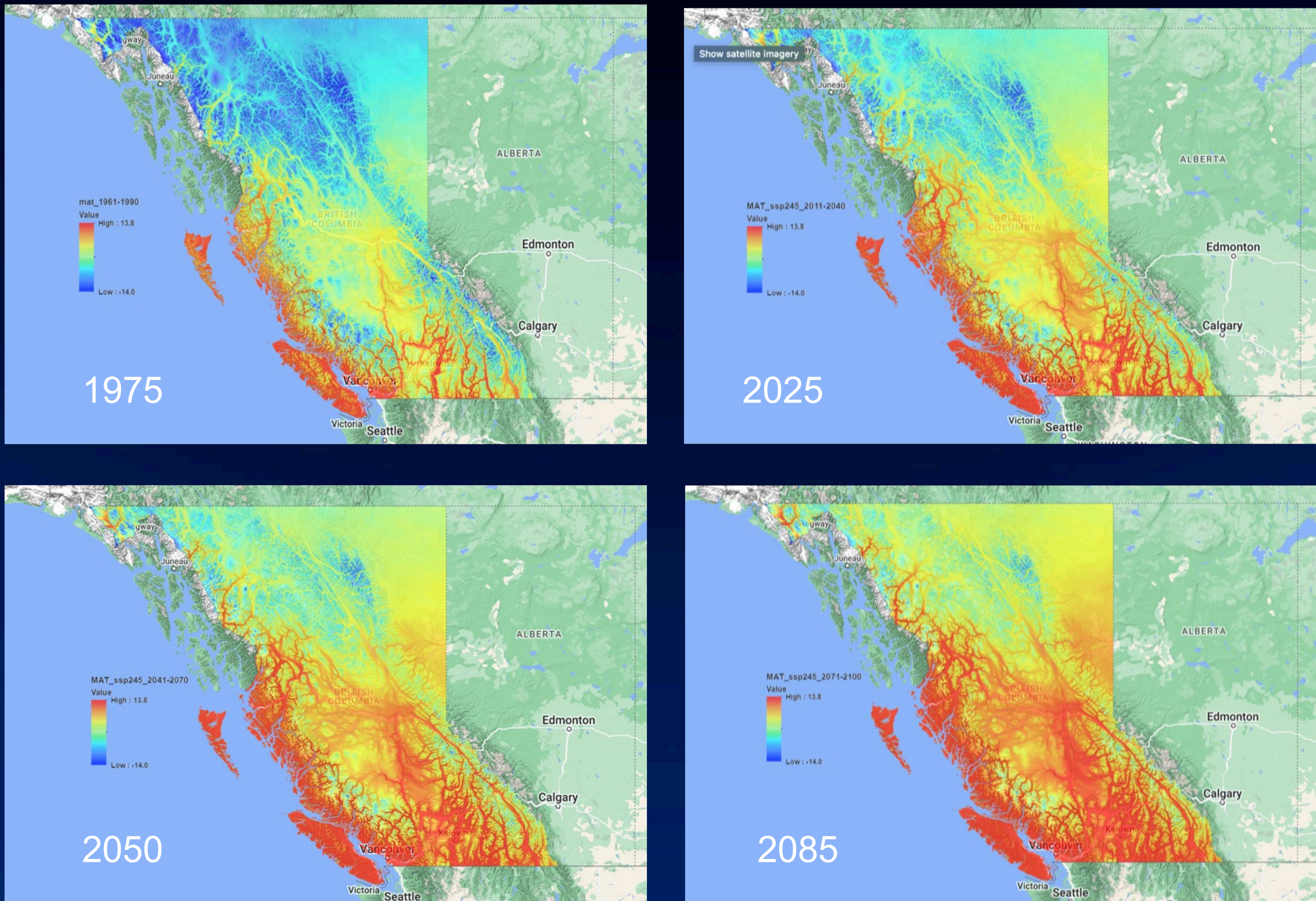
Climatic changes

- Temperature increases
- Changes in seasonality
- Changes in precipitation
- Extreme climatic events

- Increase in plant growth rates
- Changes in growing season



Predicted changes in mean annual temperature in BC



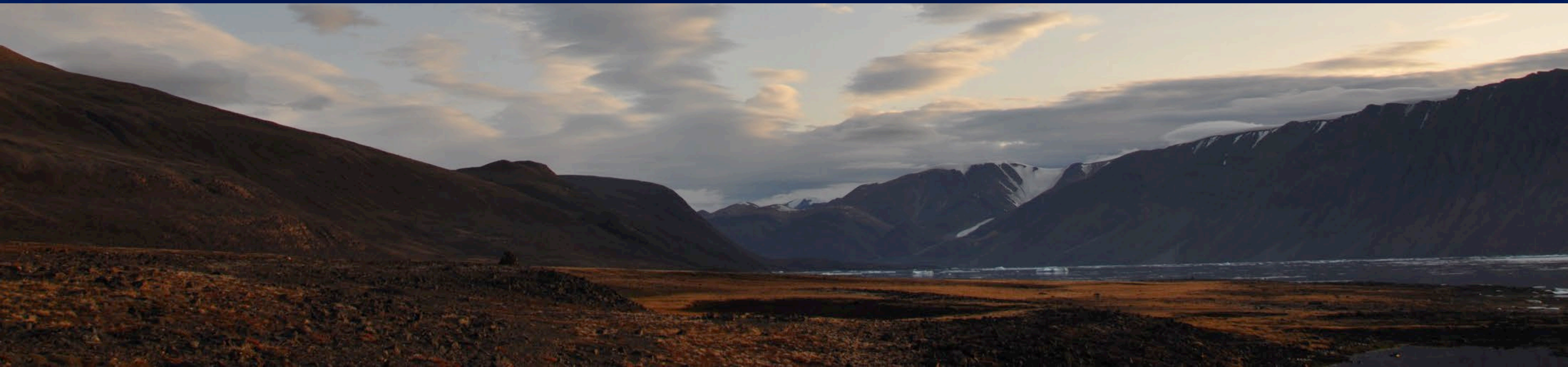
How will species, populations and communities respond to climate change?

1) Migration (seed and pollen dispersal)

2) Phenotypic plasticity

3) Evolutionary adaptation

4) Extinction

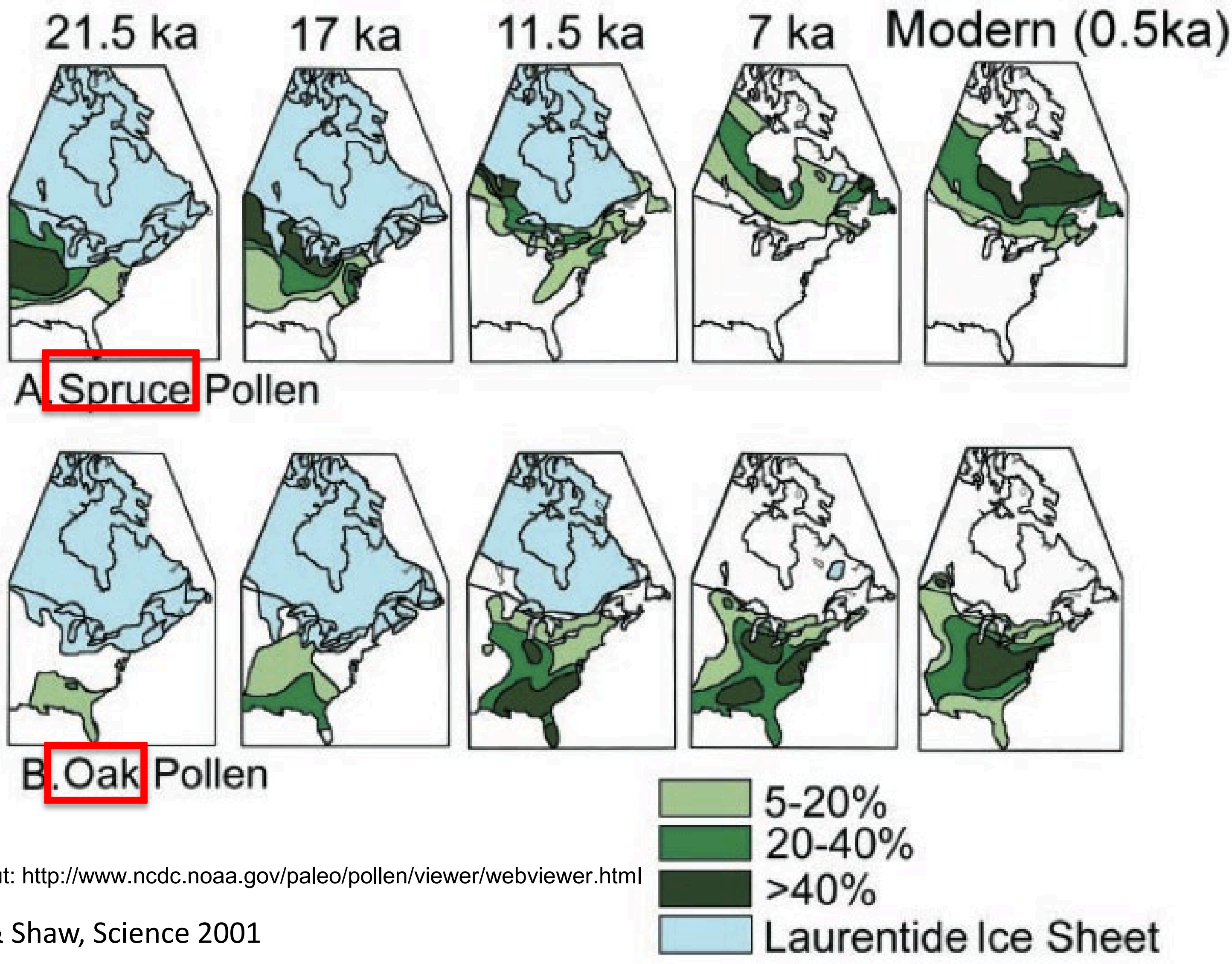


Migration

THE RECLAIM
EARTH DAY 2008
©2008 Hilary B. Price. Distributed by King Features Syndicate, Inc.
rhymeswithorange.com HILARY B. PRICE 4.22
ALL CLEAR... GO!
NOW ENTERING WILDLIFE REFUGE
EACH NIGHT, THE BEARS MOVED THE SIGN TWENTY MORE FEET OUT.

How quickly have trees moved in the past?

Pollen records suggest up to 20 km/century



Check out: http://www.ncdc.noaa.gov/paleo/pollen/viewer/webviewer.html

Davis & Shaw, Science 2001

Are estimated migration rates fast enough?

To track climatic changes in the future, range limits would need to move northward 100 km per C warming, or about 300 km per century, an order of magnitude faster than range extension occurred in the past.

→ Warming may be too fast for many tree species to track northward

Davis, Climatic Change 1989

What limits the speed of migration?

→ Seed dispersal limitation

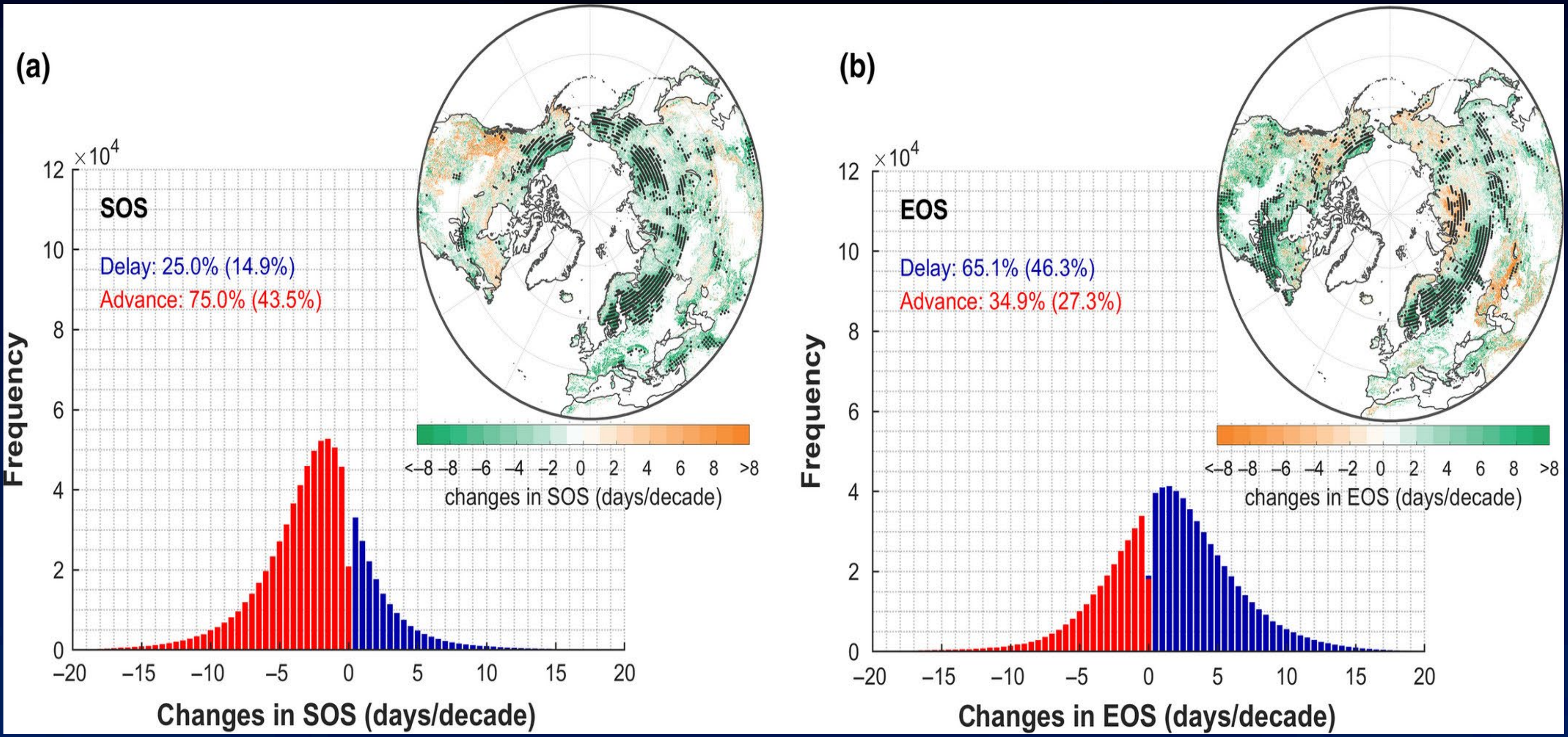
  → Migration of pollen?

→ Biotic constraints

→ Habitat fragmentation

→ Geographical barriers

Phenotypic Plasticity



Changes in start of season (SOS, a) and end of growing season (EOS, b) over the period 1982–2011.

Global Change Biology, Volume: 25, Issue: 6, Pages: 1922-1940, First published: 18 March 2019, DOI: (10.1111/gcb.14619)

Limits to the extent of plasticity

A plant can only grow so tall or flower so early → constrained by genetics.

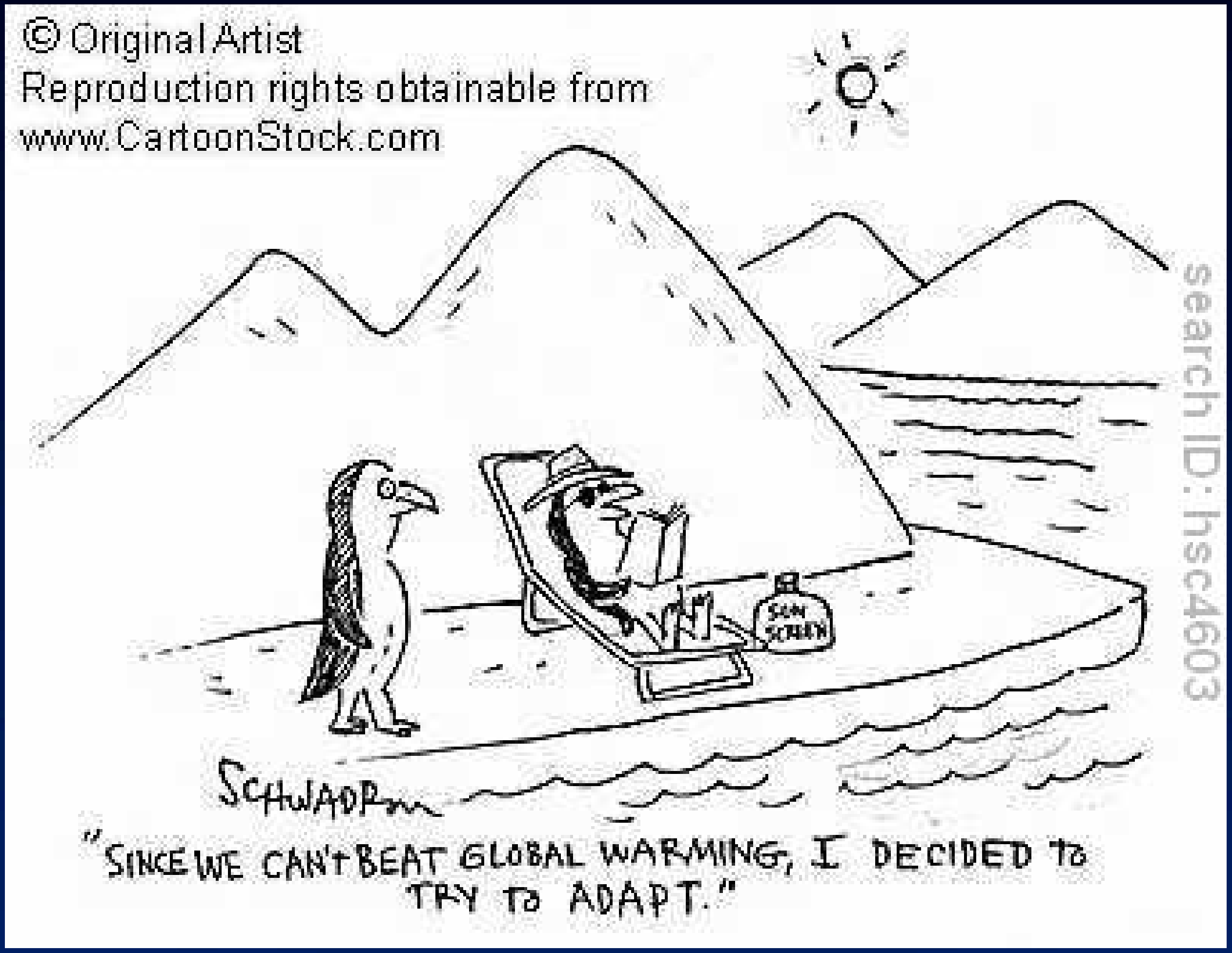
Plasticity can slow adaptive change

Why?

Plasticity is a trait that could be selected for

Selection for genotypes able to withstand increasingly variable environments

Adaptation



© Original Artist
Reproduction rights obtainable from
www.CartoonStock.com
SUN SCREEN
SCHWADRON
"SINCE WE CAN'T BEAT GLOBAL WARMING, I DECIDED TO TRY TO ADAPT."
search ID: hsc4603

Adaptation

→ Adaptation has the potential to help reduce the effects of climate change on extinction

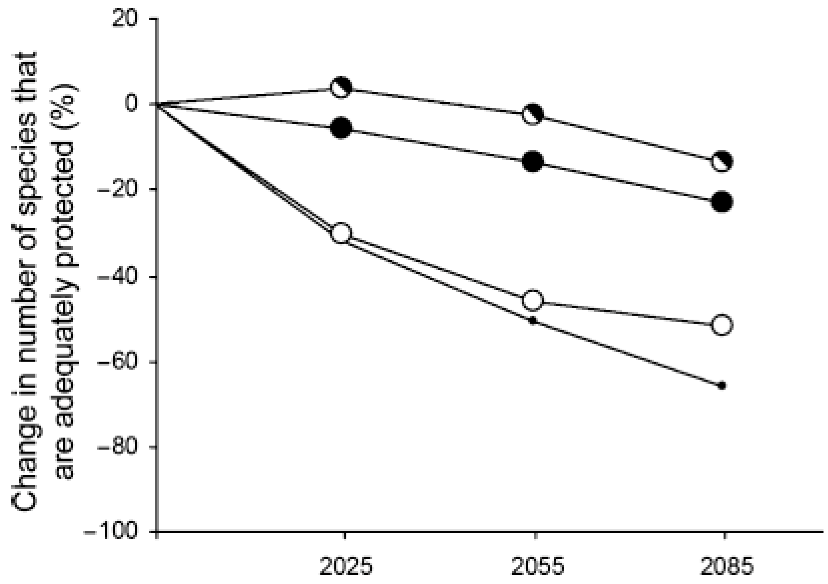
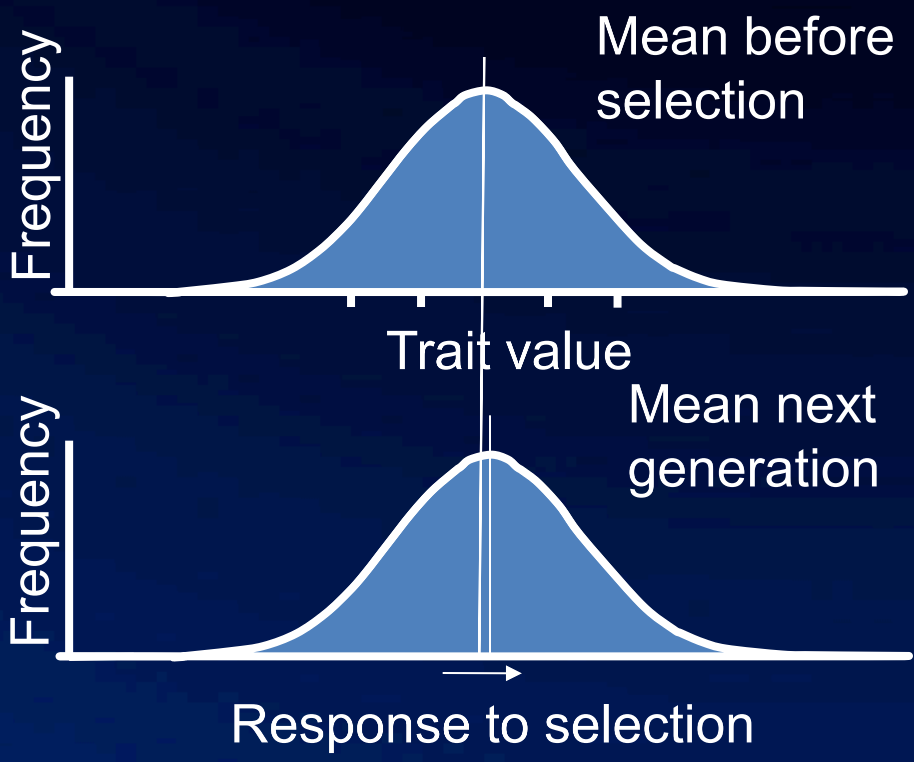


Figure 1 Change in the number of tree species predicted to be adequately conserved (cumulative cover of 10 ha, Hamann and Wang 2006) into the future, under the assumption that species are capable to adapt to changed climate, (●), migrate to suitable habitat within a reserve, (○), both, migrate and adapt, or neither (•). The analysis is based on bioclimatic envelope models for 49 tree species and 906 protected areas in British Columbia (Hamann and Wang 2006; A. Hamann and S.N. Aitken, unpublished manuscript.).

Aitken et al 2008

What is the Sustainable Rate of Adaptation?

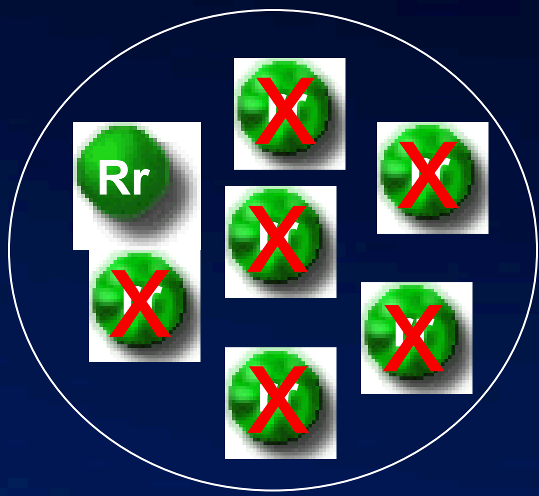


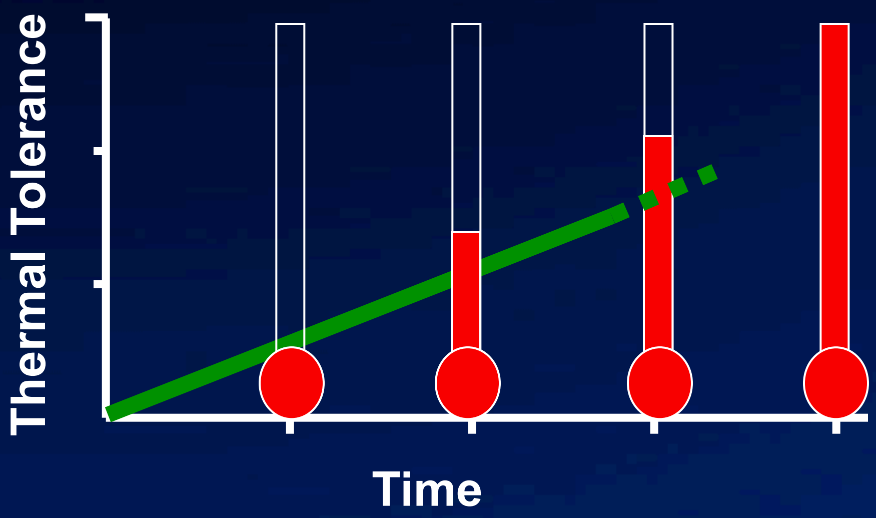
•Large populations: "a few percent" of a phenotypic standard deviation per generation (Lynch, 1996).

• Small populations: < 1% of a phenotypic standard deviation per generation (Burger and Lynch, 1995).

Why is it so slow?

- Depletion of beneficial genetic variation
- Cost of selection (Haldane, 1957)
  - The rate of adaptation is limited by the number of selective deaths that have to occur to replace one allele with another.





– If selection is too strong, the population will go extinct.

– Density-dependent “soft” selection provides a buffer against extinction.

Factors that affect speed of adaptation

Speed of adaptation

- Large Populations: ⇑ beneficial mutations
- Large Number of Genes : ⇑ beneficial mutations
- High Rate of Recombination (in large populations)
- Strong Selection: ⇑ initial rate of adaptation
- Constant Selection

- Small Populations: ⇓ beneficial mutations, drift, inbreeding depression
- Fluctuating selection
- Low trait heritability

- Gene flow: increases variability, but reduces efficiency of selection
- Genetic correlations

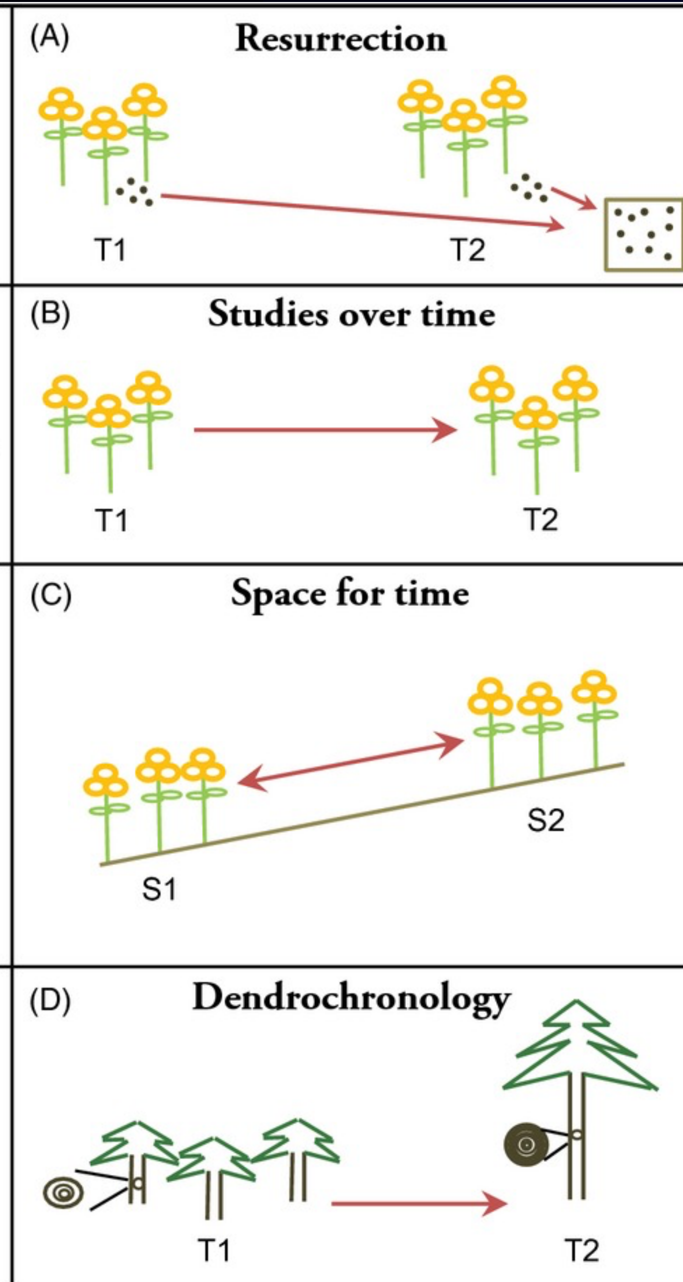
Methods for studying plastic and evolutionary responses to climate change (Frank et al. 2014)

A. Resurrection studies compare ancestors (derived from seeds at T1) and descendants (derived from seeds at T2; Time 1 = T1, Time 2 = T2) in a common garden, and provide direct evidence for evolutionary responses to climate change through time.

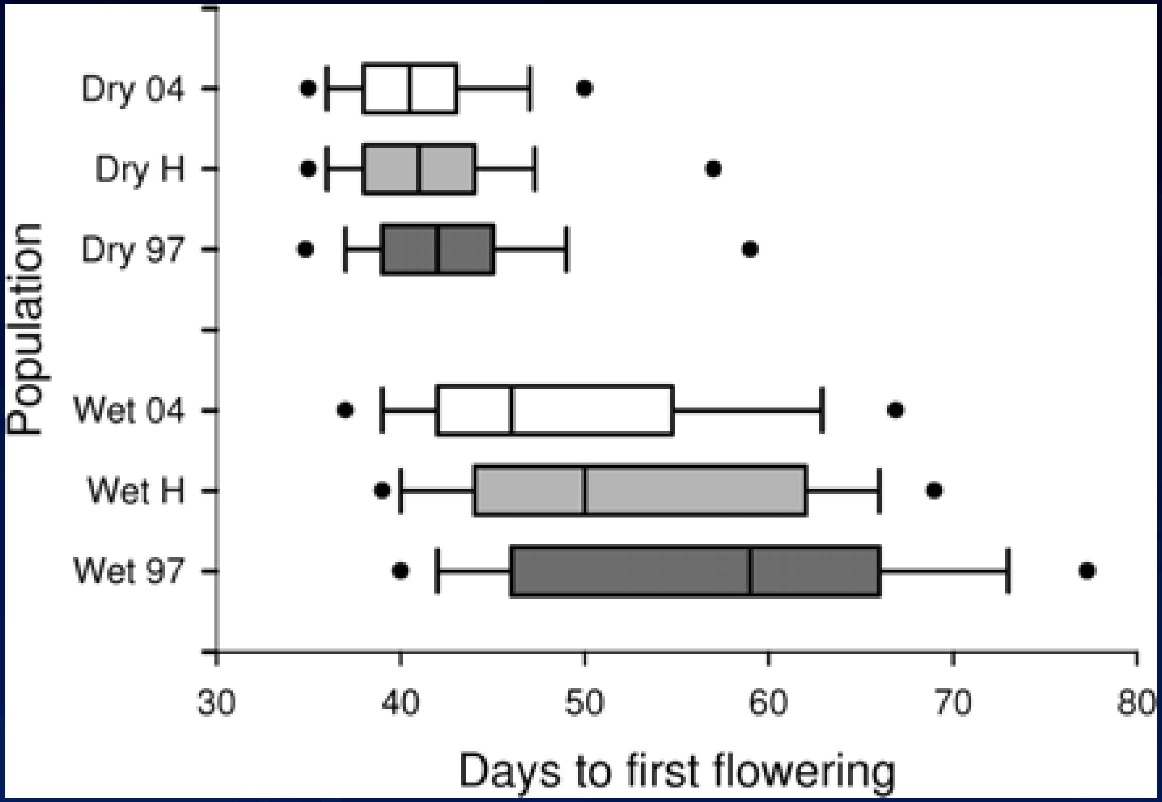
B. Field and experimental studies over time can provide evidence for climate change responses by documenting changes in phenotype or allele frequencies, but these allochronic studies do not generally distinguish evolution from plasticity.

C. Space for time studies such as reciprocal transplants use common gardens across existing climatic variation (slope here indicates elevation gradient) over space (Site 1 = S1, Site 2 = S2). These synchronic studies can be used to distinguish plasticity from local adaptation, and can be combined with quantitative genetics to help predict climate change responses, but do not test rates of responses.

D. Dendrochronology uses tree ring data to estimate species responses through time. This method often also invokes space for time (as in C) and multiple measures through time. See text for more complete description of these and other methods.



Has adaptation to climate change already occurred? Yes!



A rate of 1 Haldane corresponds to a trait change of one standard deviation per generation

Time to first flowering in *Brassica rapa*. Haldanes = 0.039 for Dry site and 0.101 for Wet site (Franks et al., 2007).

So, how will climate change affect species?

Because the rate of change is so rapid:

→ Completely new assemblages of species/communities

- → those that can evolve quickly
  - → large populations, high fecundity
  - → high genetic diversity within the populations
  - → high heritability of traits
  - → short generation times
- → those that can migrate quickly
  - → current large ranges
  - → high mobility
  - → easily dispersed seeds (long-distance dispersal)
- → those with extremely plastic phenotypes

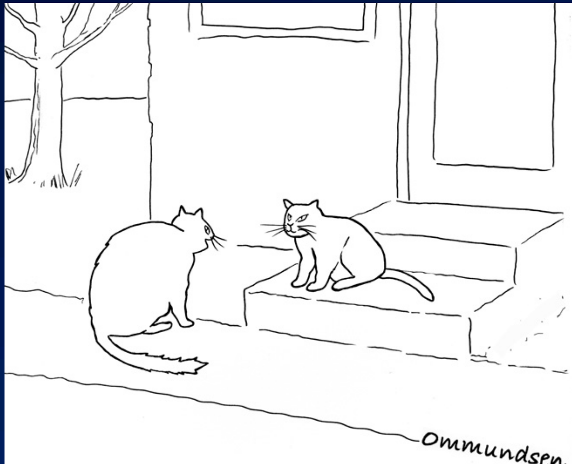
How do we use this information to minimize species extinctions as a result of climate change?

(1) Conserve genetic diversity and the capacity for adaptation

→ Conserve locally adapted *populations* (not just species)
→ Preserve large and *heterogeneous* habitats

(2) Maintain dispersal/migratory capacity of organisms

→ Create network of habitat patches
→Assisted migration?



"I found a place with a great menu. It's called a biodiversity corridor."

Unanswered questions

1) Are many populations of plants already maladapted to their current environment?

2) What is the relative importance of migration, phenotypic plasticity and adaptation in responding to climate change?

3) What selection pressures are likely to be the main cause of extinction (temperature, drought, biotic, etc.)?