

How Climate Change Affects the Physiology of Trees

Jim Downer

University of California
Cooperative Extension
ajdowner@ucdavis.edu

<http://ceventura.ucdavis.edu>

Things to consider

- Climate change: is it real?
- Tree Physiology: What is there to change
- Urban heat islands

Direct Effects

- Trees are killed?
- Trees grow more
- Trees grow less

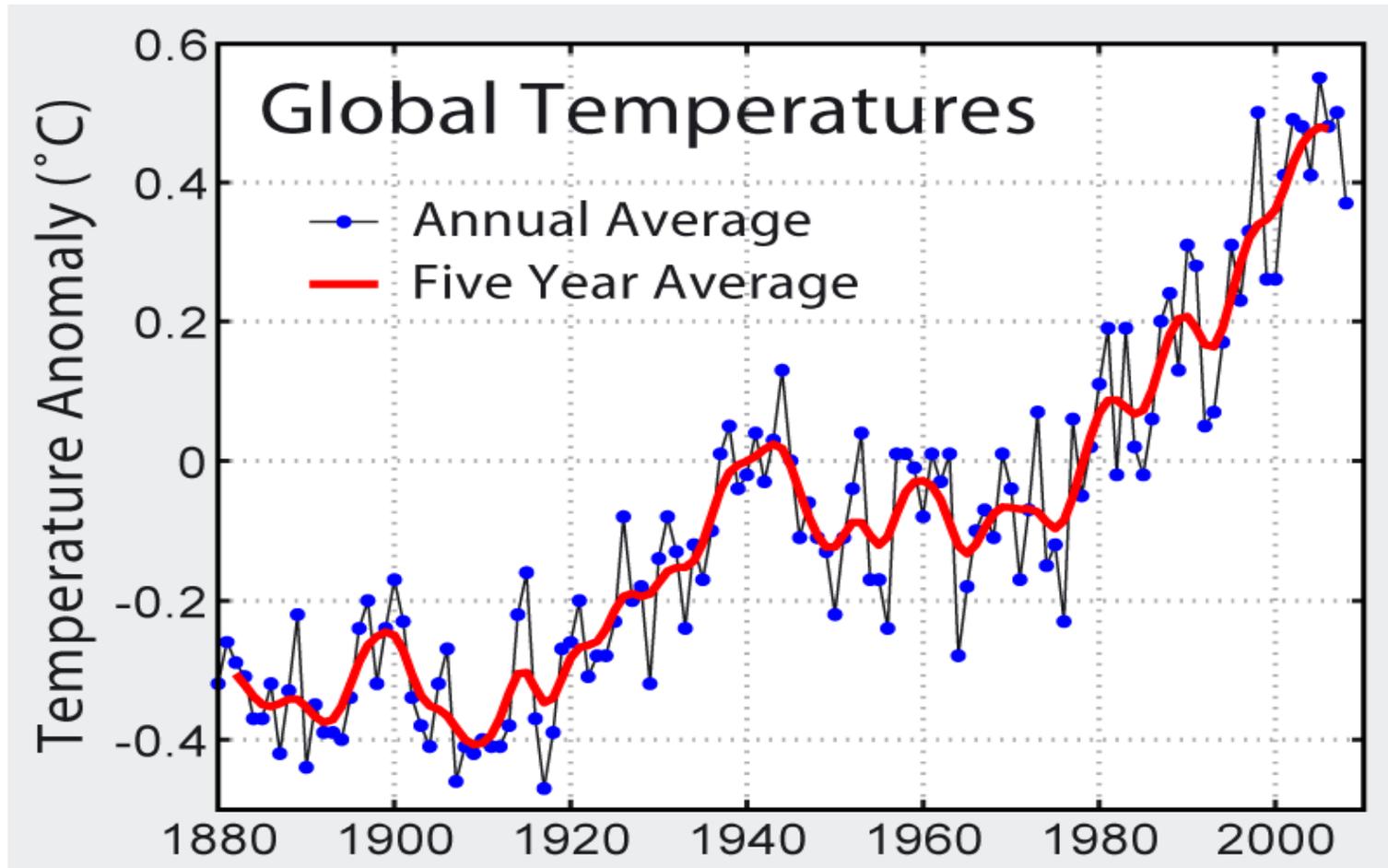


Indirect effects

- Change in population centers
- Changes in pests affect trees



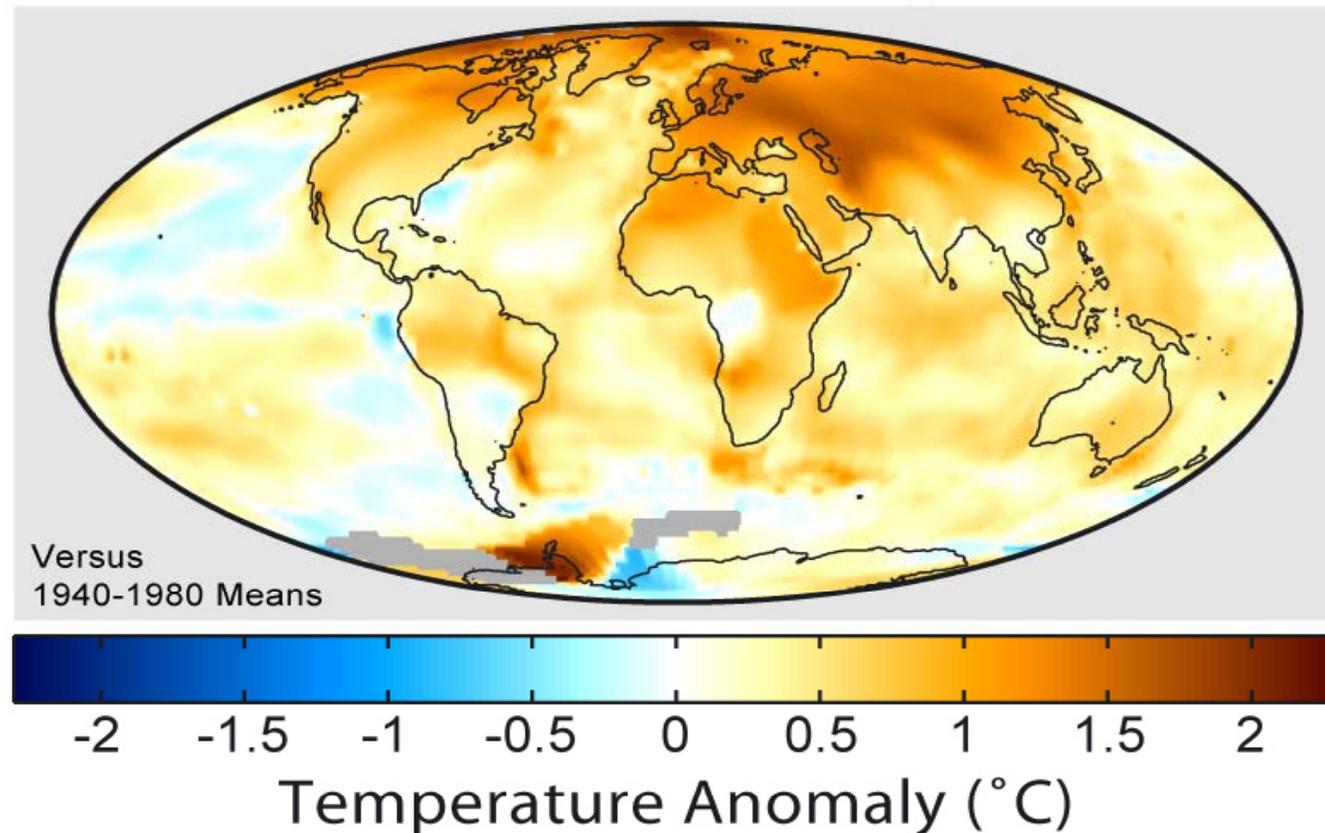
Global temperatures on the rise



From NASA Goddard Institute for Space Studies and Hansen et al., 2006 Proc
Of the Natl. Acad. Sci. 103:14288-14293

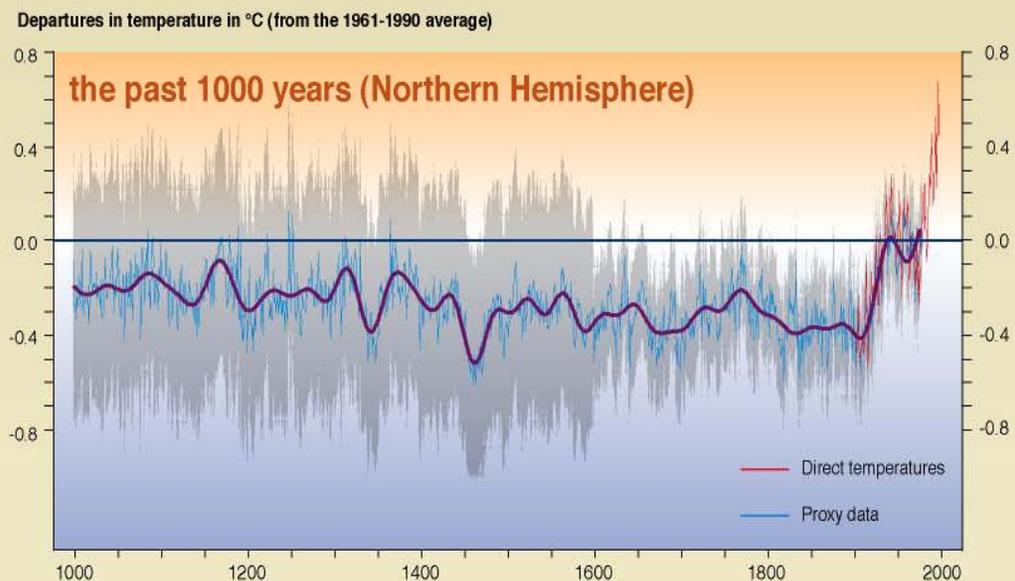
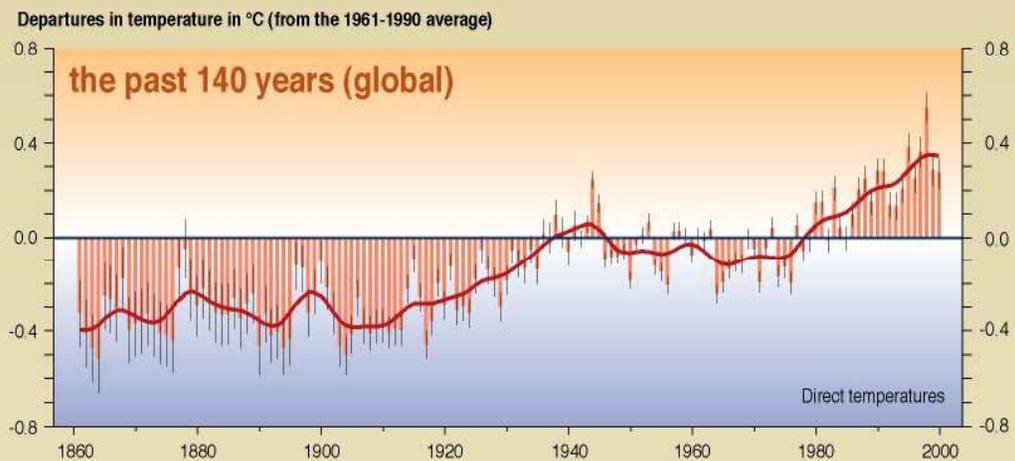
Distribution of warming temperatures is largely a northern hemisphere occurrence.

1999-2008 Mean Temperatures



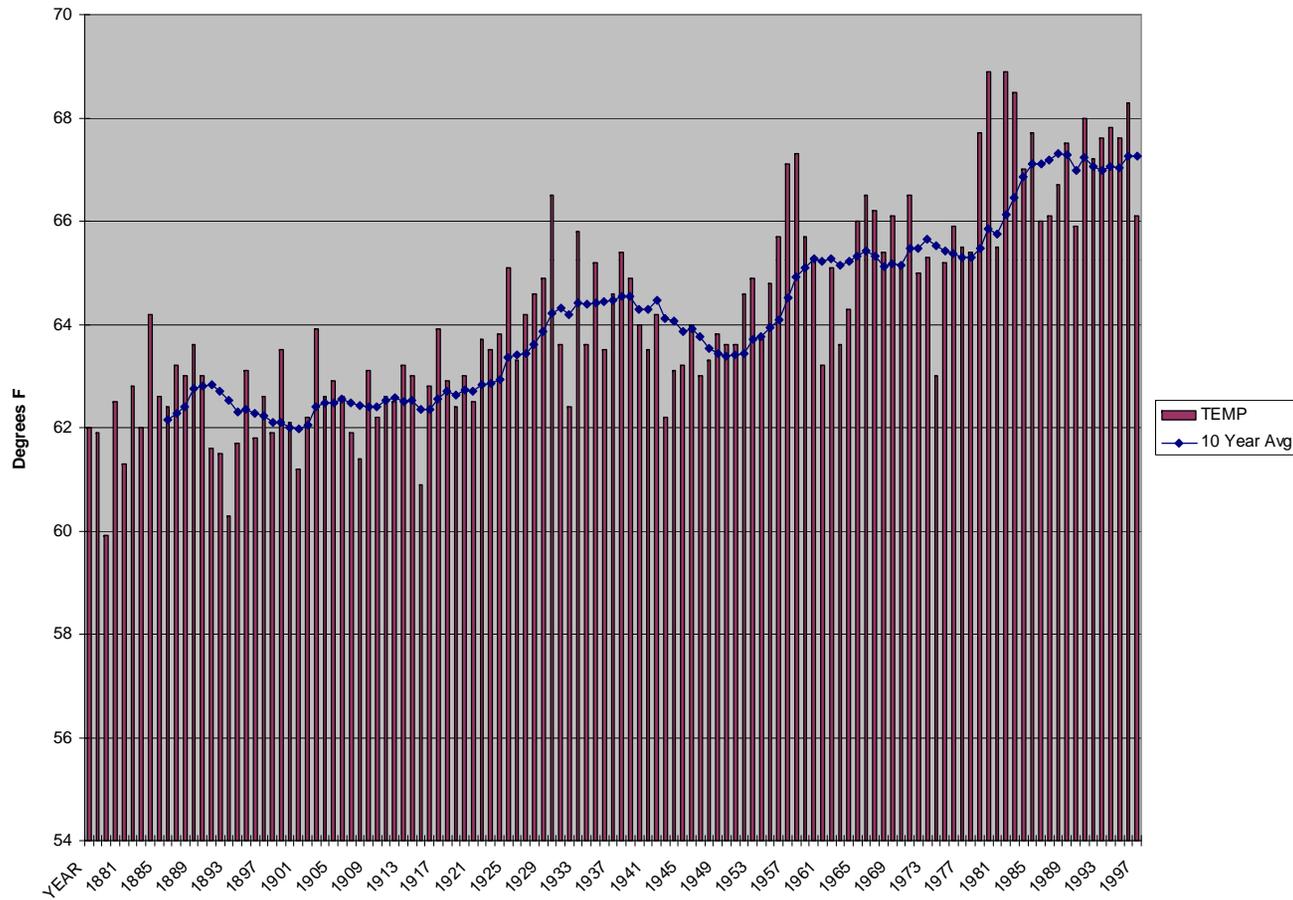
From NASA GISS (Hansen et al., 2001 J. Geophys. Res. 106:23947-23963)

Variations of the Earth's surface temperature for...



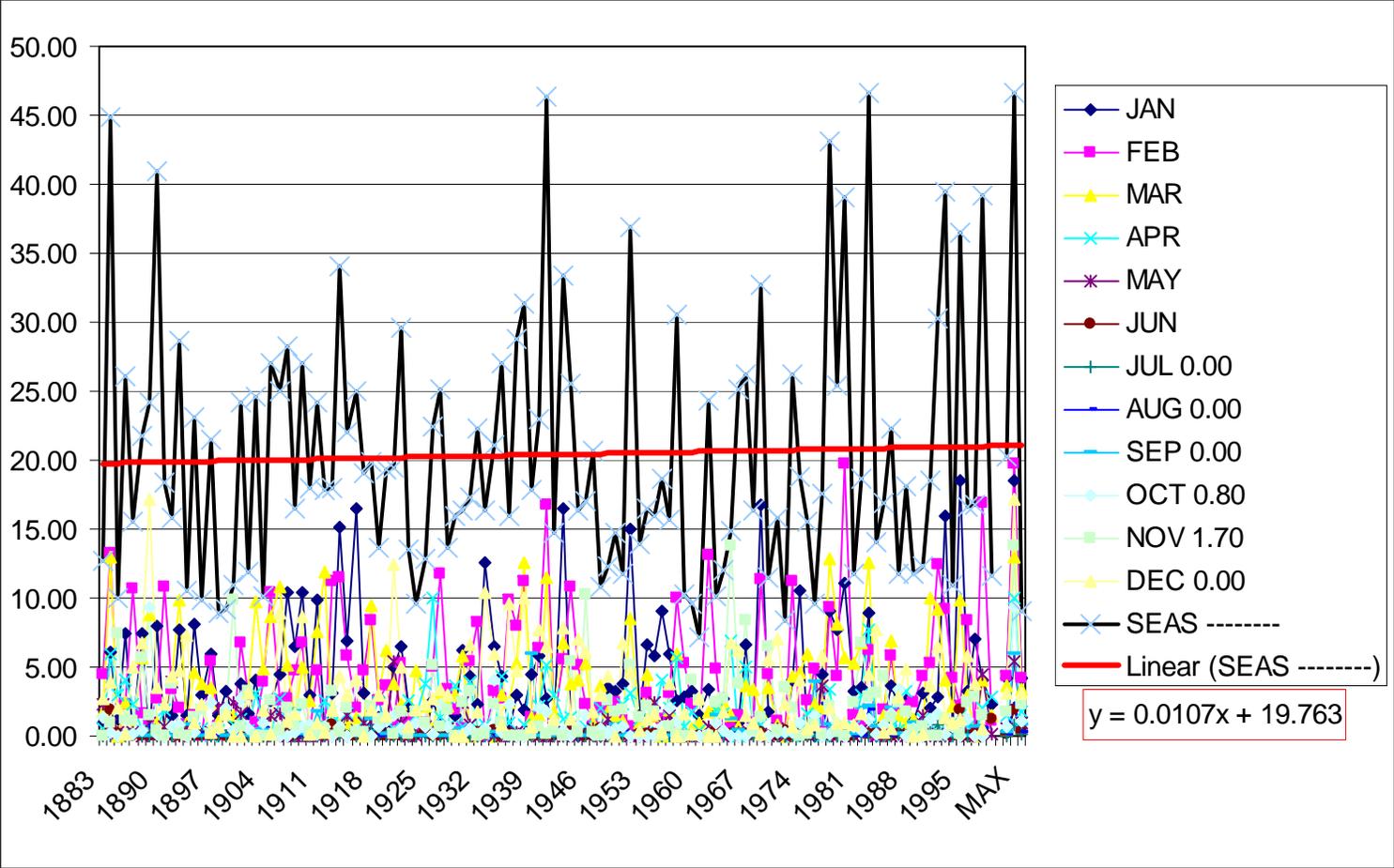
SYR - FIGURE 2-3

Los Angeles Temperatures



From NOAA

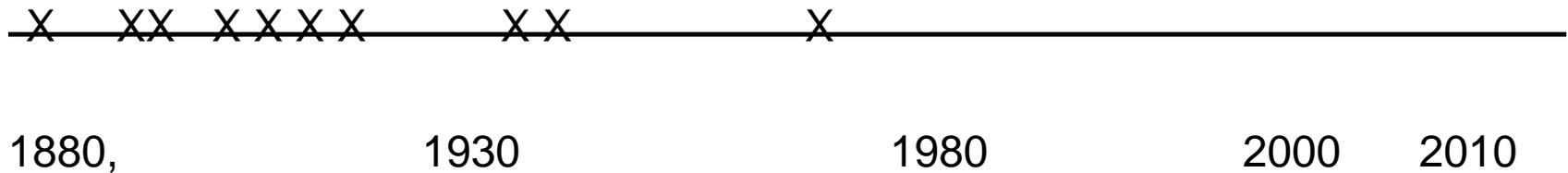
Rainfall in Pasadena 1883 to 1999



From NOAA: http://www.wrh.noaa.gov/lox/climate/climate_intro.php

Number of times it has rained on the Rose Parade

- 9

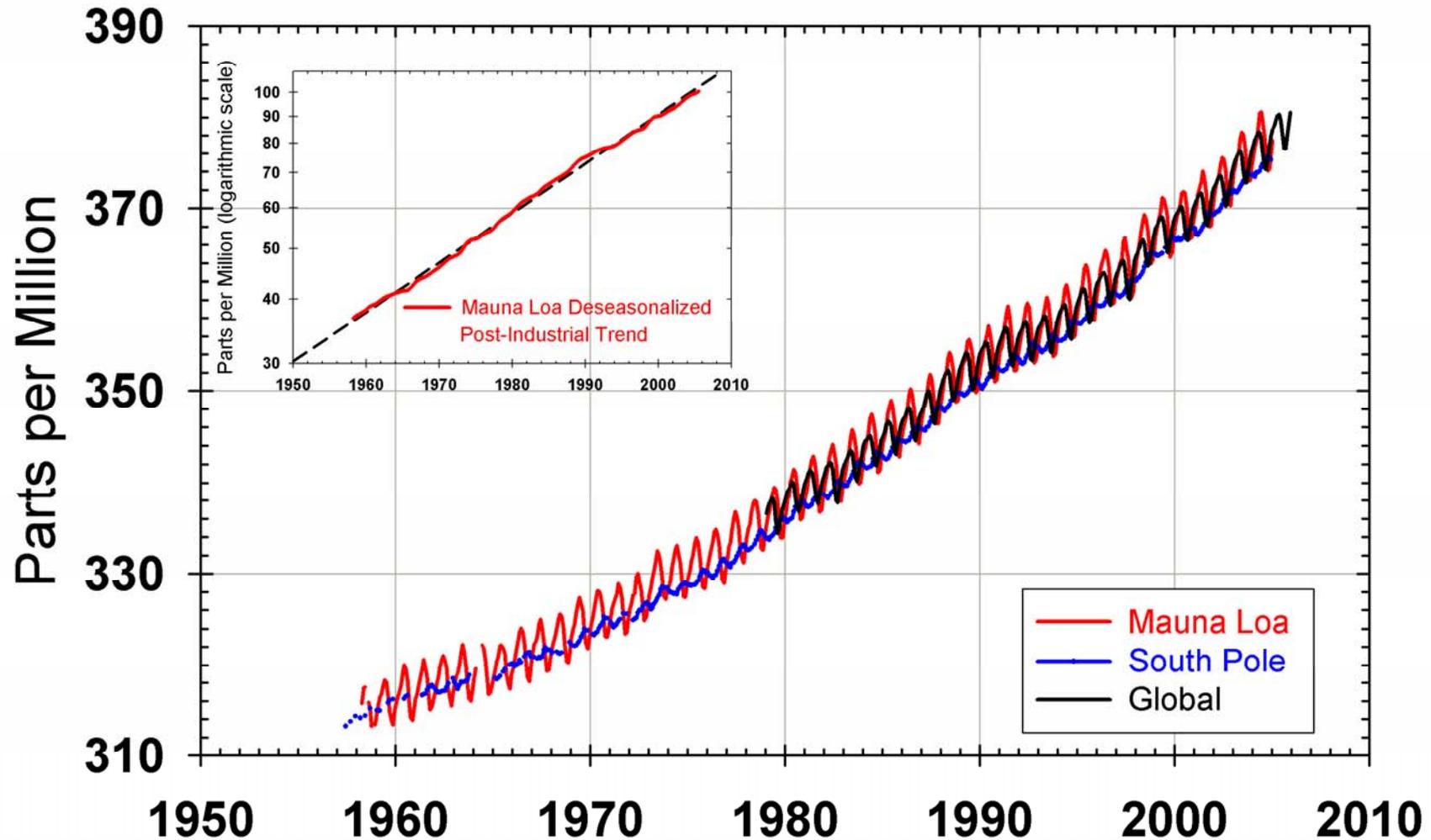


What is real?

Carbon Dioxide concentration is increasing!

- 21st century levels are double the concentration that has prevailed over the last 420,000 years according to air bubble data in arctic ice.
- Plants in the world today evolved in a “low CO₂” environment
- High CO₂ levels have not existed on earth since the very warm Cretaceous period 20m years ago.
- Since the industrial revolution CO₂ has been increasing by 1-3ppm per year

CO₂ Concentration Over Time



From Wikipedia

- The Keeling Curve also shows a cyclic variation of about 5 ppm in each year corresponding to the seasonal change in uptake of CO₂ by the world's land vegetation. Most of this vegetation is in the [Northern hemisphere](#), since this is where most of the land is located. The level decreases from northern spring onwards as new [plant](#) growth takes carbon dioxide out of the atmosphere through [photosynthesis](#) and rises again in the northern [fall](#) as plants and [leaves](#) die off and decay to release the gas back into the atmosphere.[\[14\]](#)

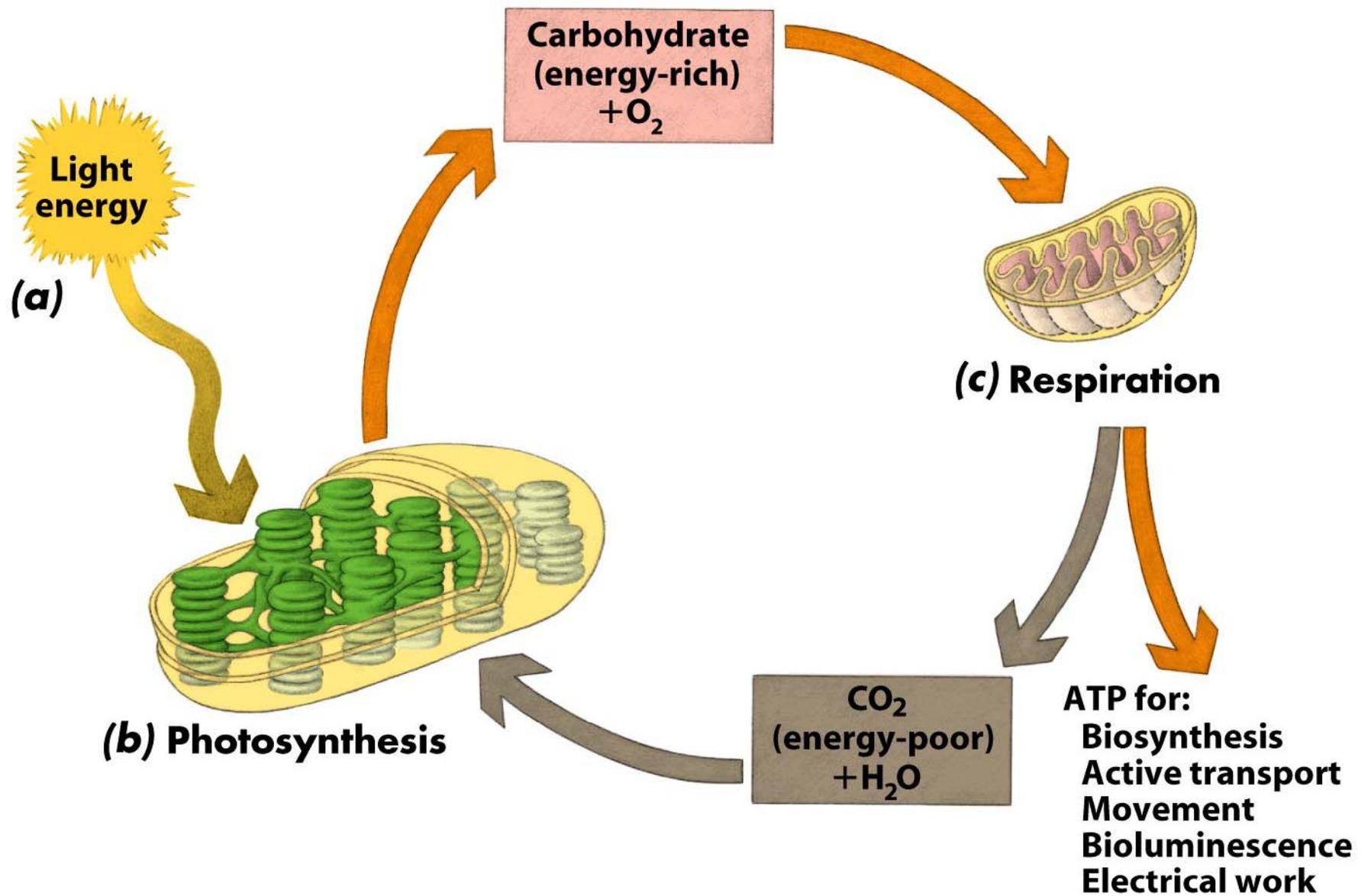
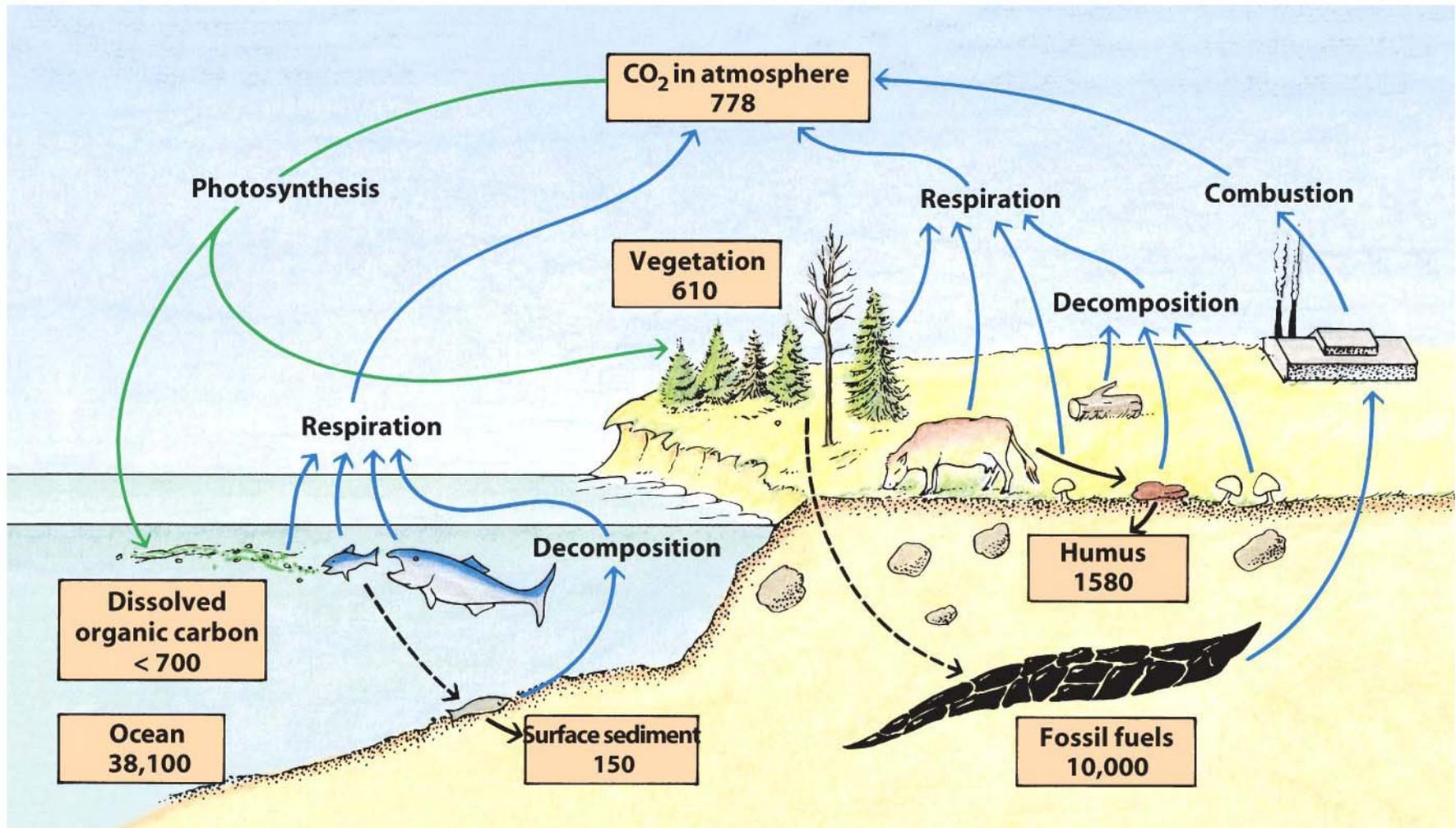


Figure 5-1
Biology of Plants, Seventh Edition
 © 2005 W. H. Freeman and Company

Photosynthesis

- $6\text{CO}_2 + 6 \text{H}_2\text{O} + \text{E} \rightarrow 2\text{C}_3\text{H}_6\text{O}_2 + 6\text{O}_2$
- Carbon Dioxide is turned into trees or woody biomass and sequestered there for a time. But this is minimal compared to carbon retained in the ocean
- Increasing CO_2 regulates stomatal closing, thus decreasing water loss.



Chapter 7 Essay
Biology of Plants, Seventh Edition
 © 2005 W. H. Freeman and Company

From Raven et al., 2005

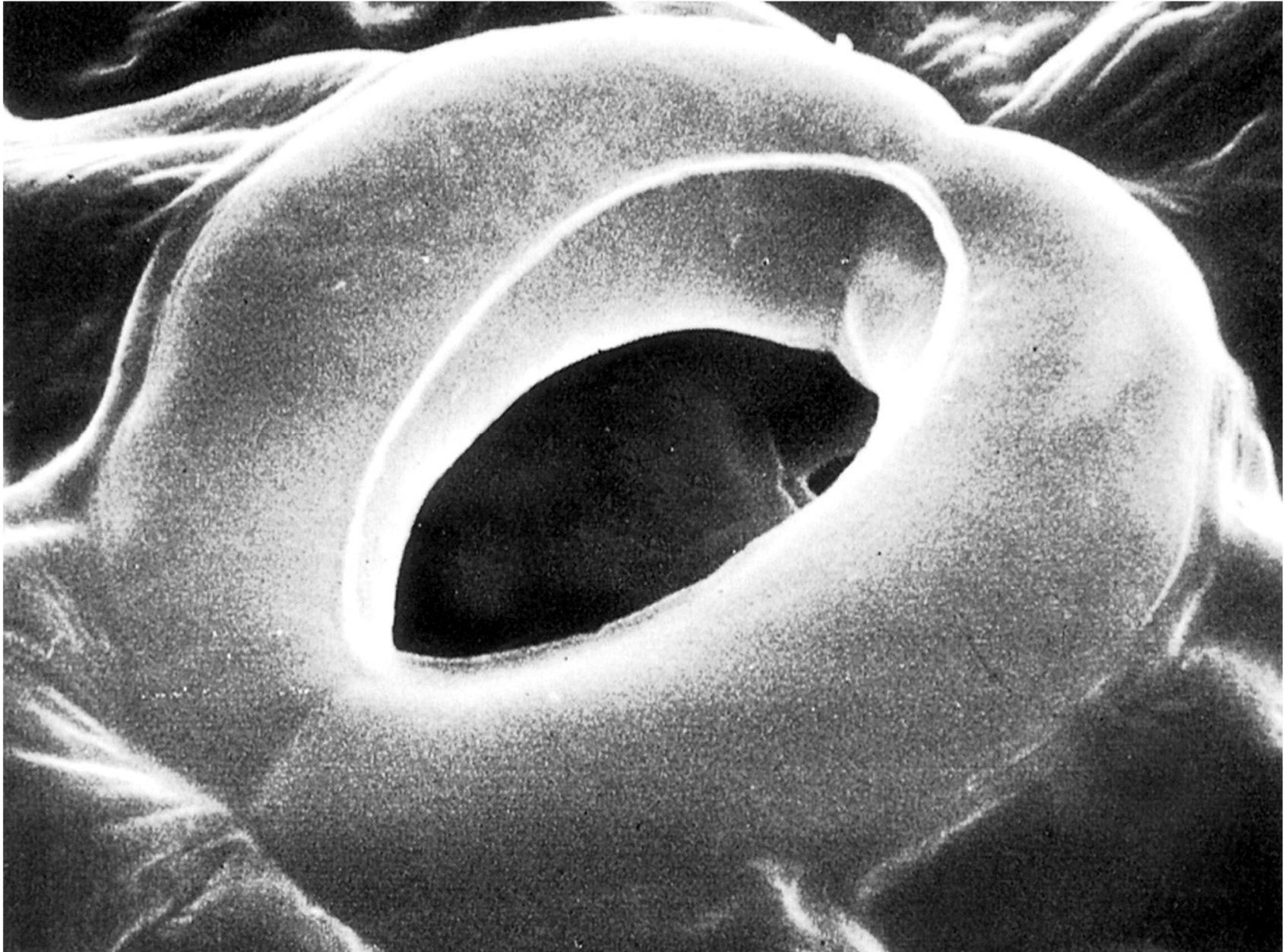


Figure 30-2a
Biology of Plants, Seventh Edition
© 2005 W. H. Freeman and Company

What does it mean to trees to have more CO₂ in the atmosphere?

- It will be warmer due to the greenhouse effect and thus the range of where trees grow will change.
- Higher [CO₂] support higher photosynthetic rates
- Greater growth of trees
- Trees with C₃ photosynthetic pathways are favored over plants with the C₄ pathway

Biomass and Toxicity response of Poison ivy to elevated CO₂

Mohan et al. 2006. PNAS

- Elevated CO₂ in a forest ecosystem:
 - Increased water use efficiency, growth, and biomass of Poison Ivy
 - increased urushiol the toxicant in poison ivy
 - Toxicodendron will become more abundant and more toxic as [CO₂] rises.



Affects on Forests

- Air temperature increases
- Precipitation amount decreased
- Atmospheric CO₂ concentrations
- Increased frequency and severity of wildfires
- Increased frequency and severity of extreme weather events
- Indirect effects on pollution, ie. tropospheric ozone levels

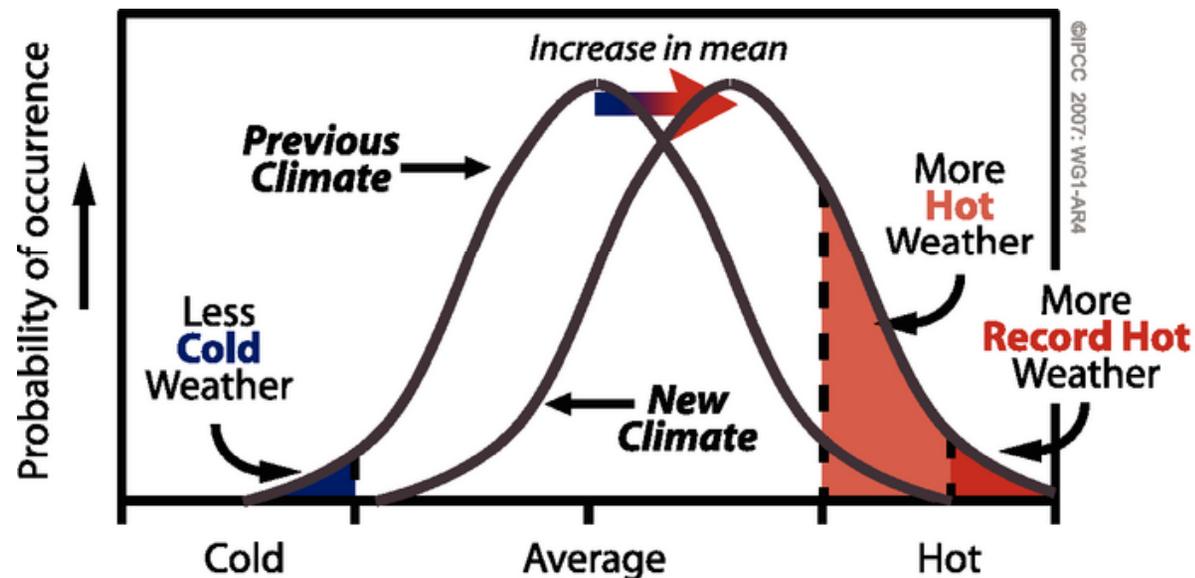
From the intergovernmental panel on climate change, 2007. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, Martin L., Canziani, Osvaldo F., Palutikof, Jean P., van der Linden, Paul J., and Hanson, Clair E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, 1000 pp.

IPPC Conclusions

- Increased forest growth (10-20%) over the next century
- Increased wildfire incidence associated with warmer climates and drought—increased areas associated with fire danger
- Long term affects of fire will be dependent on human fire management activities
- Increasing insect outbreaks “virtually certain”

More from IPCC conclusions about changes in North America

- Warmer and fewer cold days and nights over most land areas
- Warmer and more frequent hot days and nights over most land areas.



What trees will be affected?

- Although C₃ plants (trees) will benefit from increased CO₂, plants with C₄ metabolism (not many trees/Euphorbia) will be better able to survive the transient heat increases and drought due to better water use efficiency and lower nitrogen requirements.

Warming and Earlier Spring Increase Western US Forest Wildfire Activity

Westerling et al. 2006 Science

- Forest fires tied to climate change
- Increased length and duration of fire
- Tied to earlier spring and longer summer droughts in Western United States Forests



Insect pests

Trumble and Butler, 2009 *California Agriculture* 63(2):73-78.

- Range expansions of insects that are already here
- Arrival of more new insect pests
- Changes in ecosystems that allow some insects to soar to high populations while forcing others to near extinction.
 - Loss of parasitoid complexes that exert bio control
 - Displacement of native ant species by the Argentine ant

Pests and Diseases will increase

- Bark Beetles will continue to decimate conifers in North America
- Bark Beetles and other tree damaging pests will continue to expand their range
 - Mountain Pine Beetle
- Due to warming trends pests not previously found in California will arrive and begin to damage trees and other plants

California Black Walnut



Thousand Cankers “Disease”

- *Geosmithia morbida* associated with walnut twig beetle
- It takes a thousand cankers to kill the tree



Thousand Cankers Disease

- A new disease? A new pest?
- Or... result of an insect taking advantage of drought stressed trees in a warming climate.

Redwood Decline



How does climate affect redwood decline?

- Growing non-adapted forest plants as specimen trees in increasingly hotter climates causes stress!
- Stress makes trees conducive to fungal attack by weak pathogens
- As water becomes more expensive and dry downs more severe, salinity is exerted on the tree, increasing its stress!

Climate change will exacerbate the mortality spiral for poorly adapted trees like Redwood

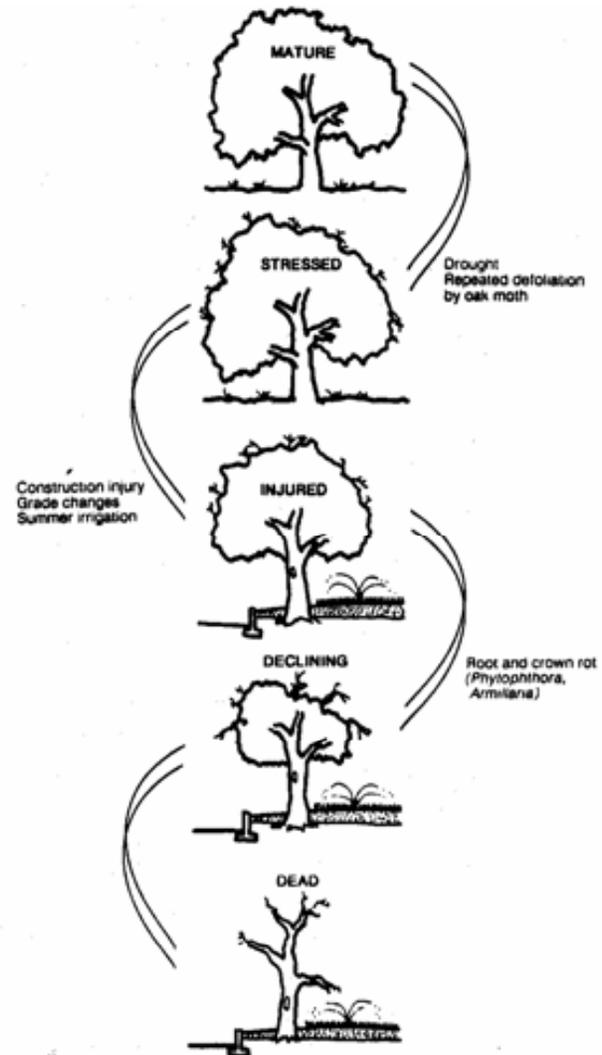


Figure 1. Proposed mortality spiral for California live oak (*Quercus agrifolia*).

Scorch diseases

Xylella fastidiosa

- Vectored by the glassy winged sharpshooter
- Increased range of the vector
- Increased host range of the scorch disease
- As the climate warms the disease will spread.



What else can happen?

- Assuming a drier hotter climate...
 - More dust- drier soils
 - Increased damage from mites
 - Increased damage from wood boring insects
 - Increased salinity
 - Increased root rot
 - Less available and more expensive water

What can we do about it?

- Plant more Trees?
- Maintain what we have?
- Shift tree populations to more adapted species that require less water.
- Remove trees
 - To encourage health of remaining individuals
Thin the Stand
- Allow more space for trees to grow
 - Decreases tree stress