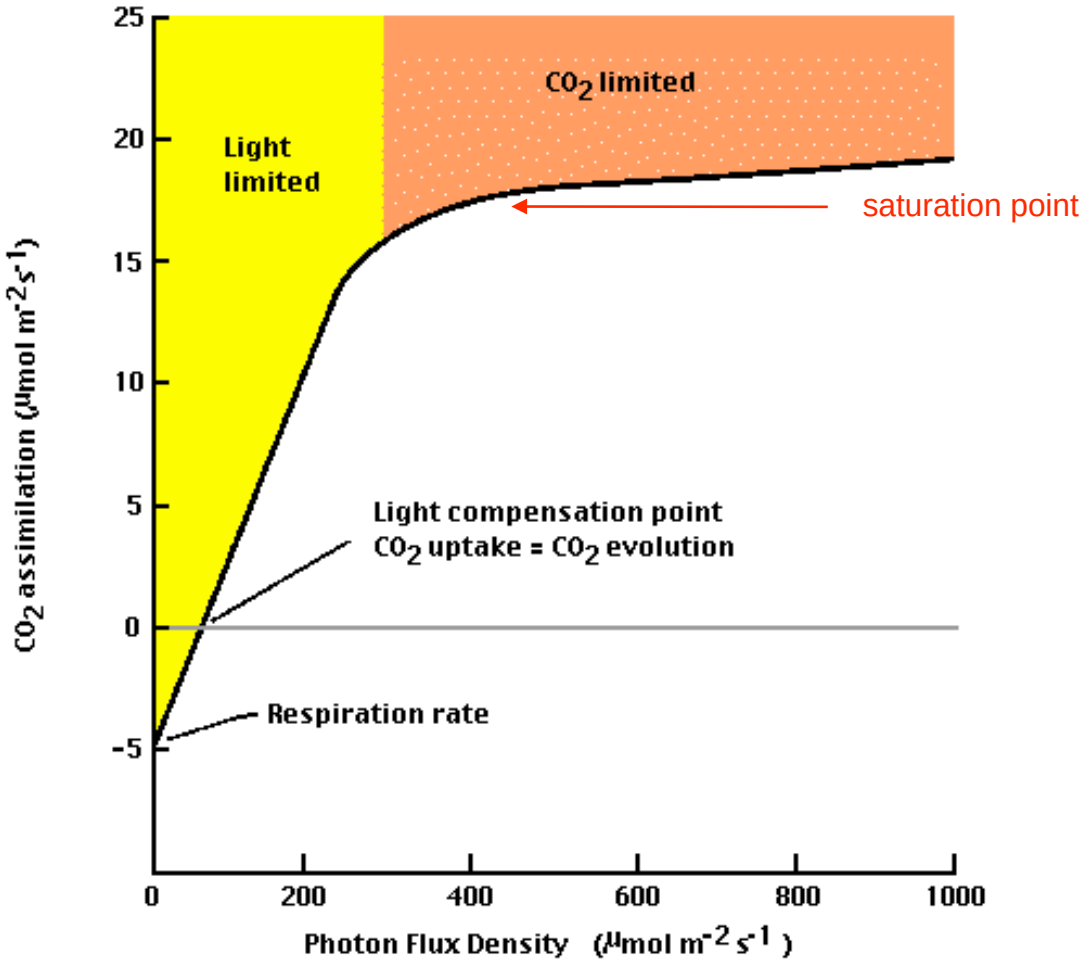
# Physical environment

## Photosynthesis as a function of available PAR

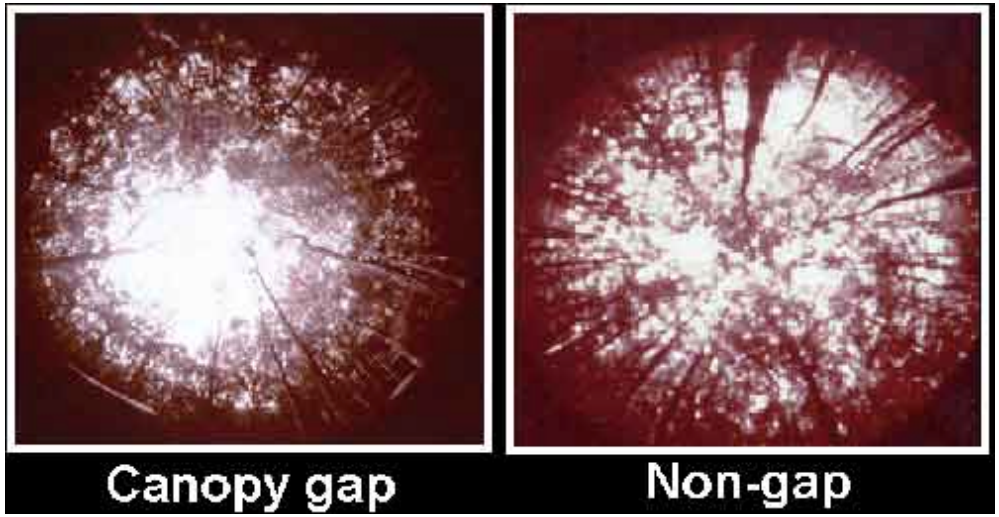



plantphys.info/Plant_Physiology/photoeco.html

# Physical environment

How does canopy cover affect light penetration?

**PAR = 185 µmol/m2/s  PAR = 67 µmol/m2/s**




www.uga.edu/srel/ESSite/MMLight_acclimation.htm

# Physical environment

## Light penetration into canopy

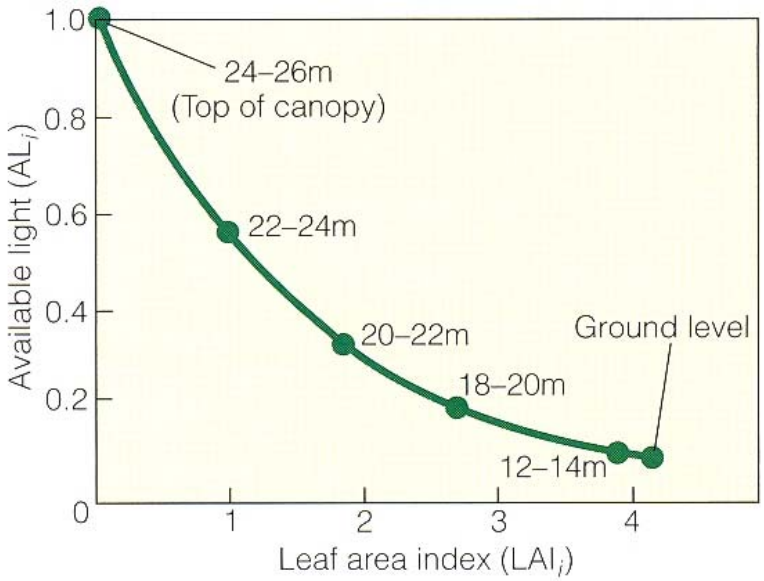



**Figure 1** | Relationship between leaf area index above various heights in the canopy ($LAI_i$) and the associated values of available light ($AL_i$), expressed as a proportion of PAR at the top of the canopy.

*Leaf area index =*
*surface area of leaves/ground area*

Smith and Smith, 2006

# Physical environment

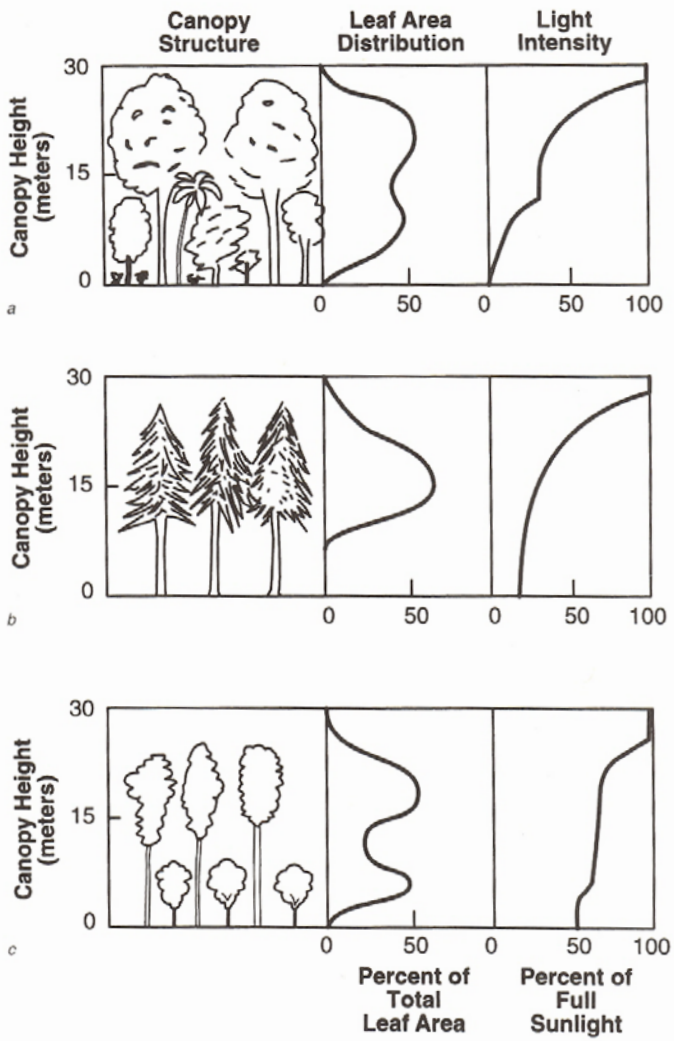



**Figure 8.5.** Canopy structure, leaf area distribution, and light intensity in a wet tropical (*a*), western conifer (*b*), and a trembling aspen ecosystem (*c*). Notice the relationship between canopy structure and the distribution of leaf area within each forest. Differences in the vertical distribution of leaf area result in dramatically different light profiles within these ecosystems.

Barnes et al., 1998

*Which has more understory vegetation?*

# Physical environment

## Light availability to understory: variability by vegetation type

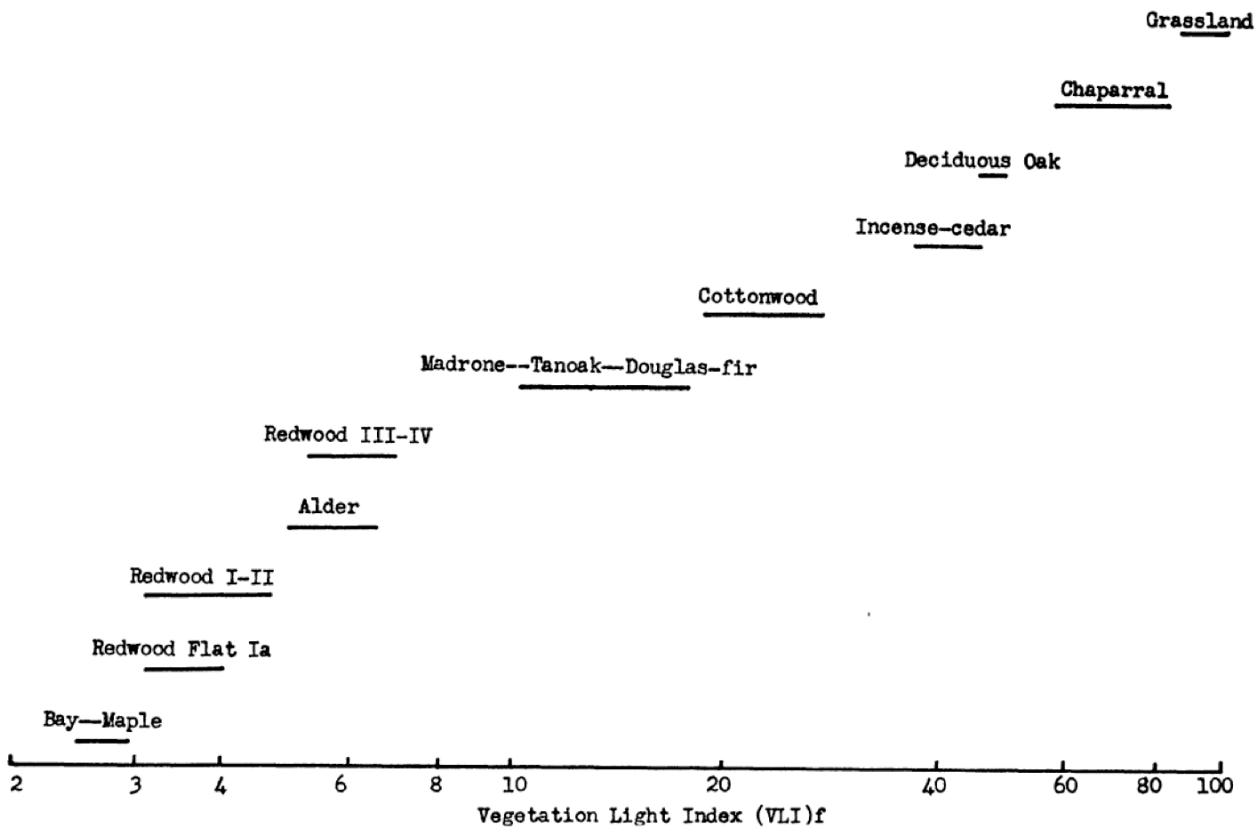



FIG. 11. Distribution of vegetation types in relation to a Vegetation Light Index (VLI)f based upon the frequency of non-arboreal species.

% of full daylight at 1 m

Waring and Major, 1964

# Physical environment

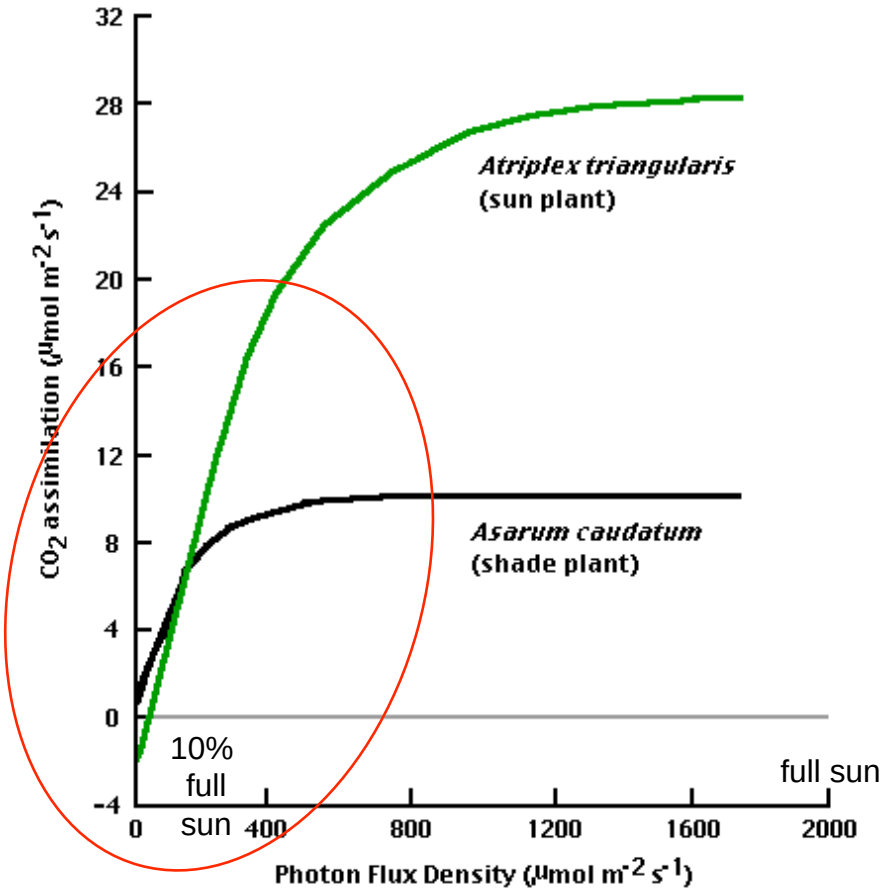
Canopy: 90% of photosynthesis

Understory: 10% of photosynthesis on only 1% of light available at top of the canopy

library.thinkquest.org/26252/explore/3.htm Images: Steven Holt

# Physical environment

## Shade-tolerant plants are more efficient at low-light levels

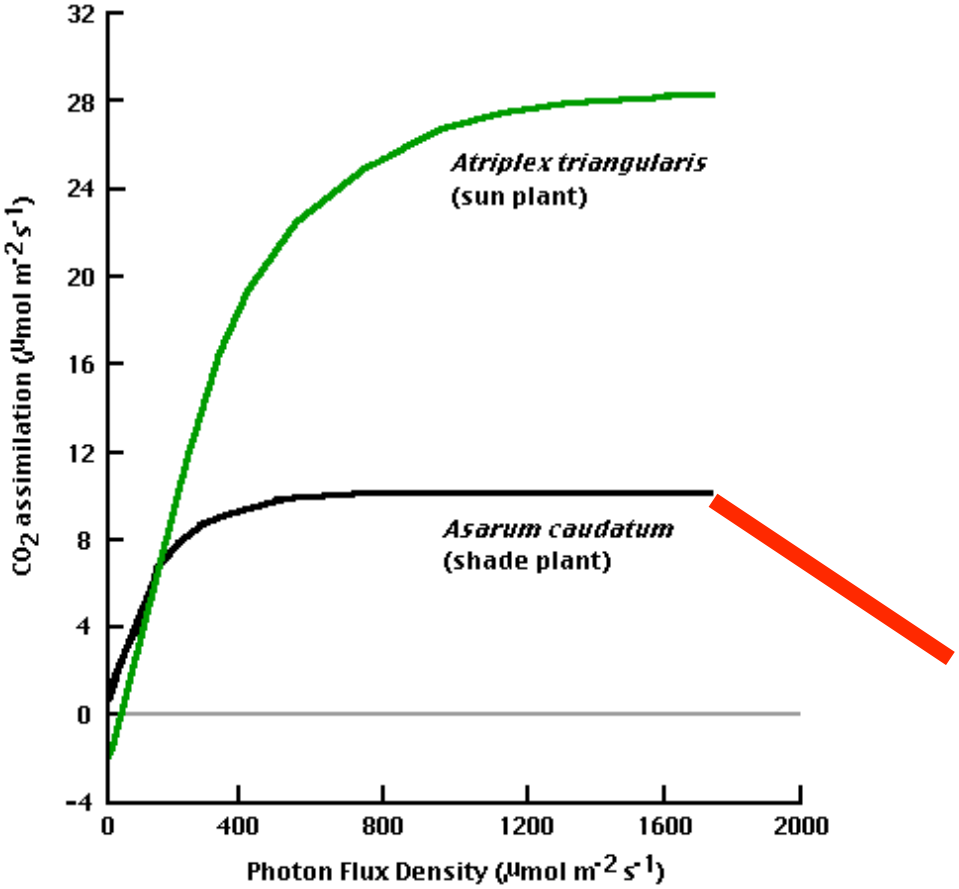



Shade tolerant species reach light saturation at 5-10% of full sunlight, e.g., red maple (*Acer rubrum*), American beech (*Fagus grandifolia*)

plantphys.info/Plant_Physiology/photoeco.html

# Physical environment

## Too much light: photoinhibition




plantphys.info/Plant_Physiology/photoeco.html

# Physical environment

## Adaptations to light

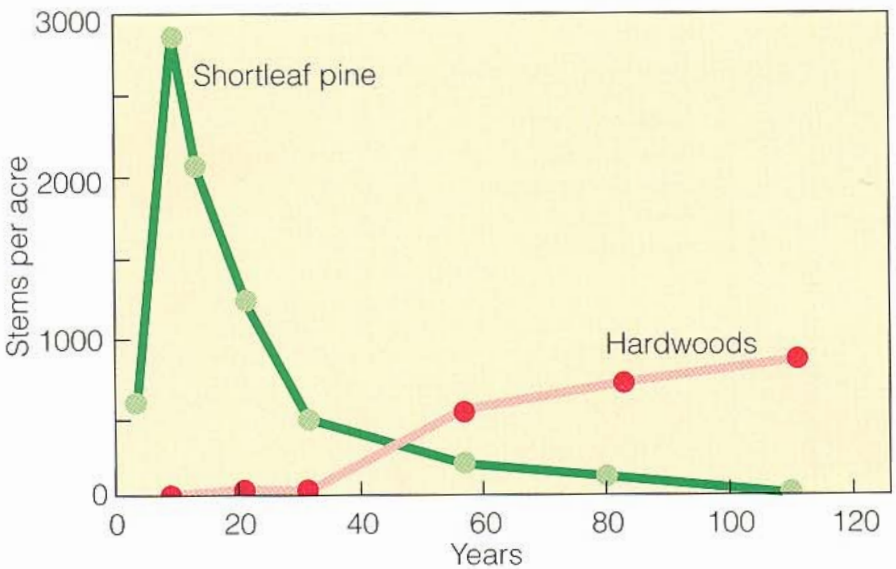



**Figure 18.6** | Decline in the abundance of shortleaf pine (*Pinus echinata*) and increase in the density of hardwood species (oak, *Quercus*, and hickory, *Carya*, species) during secondary succession on abandoned farmland in the Piedmont region of North Carolina. (Adapted from Billings 1938.)

**Figure 18.7** | A kelp forest off the Aleutian Islands of Alaska: *Cymathera triplicata* (foreground); *Alaria fistulosa* (rear). Kelp forests in the eastern and northern Pacific commonly have complex three-dimensional structure, with many coexisting species. As in coral reefs, shading is a major mechanism of intraspecific and interspecific competition.

Smith and Smith, 2006

# Physical environment

## UV Radiation Controls on Species Distributions

### Escape of zooplankton in water column from UV radiation

Concentration higher in water column without UVB

Concentration lower in water column with UVB

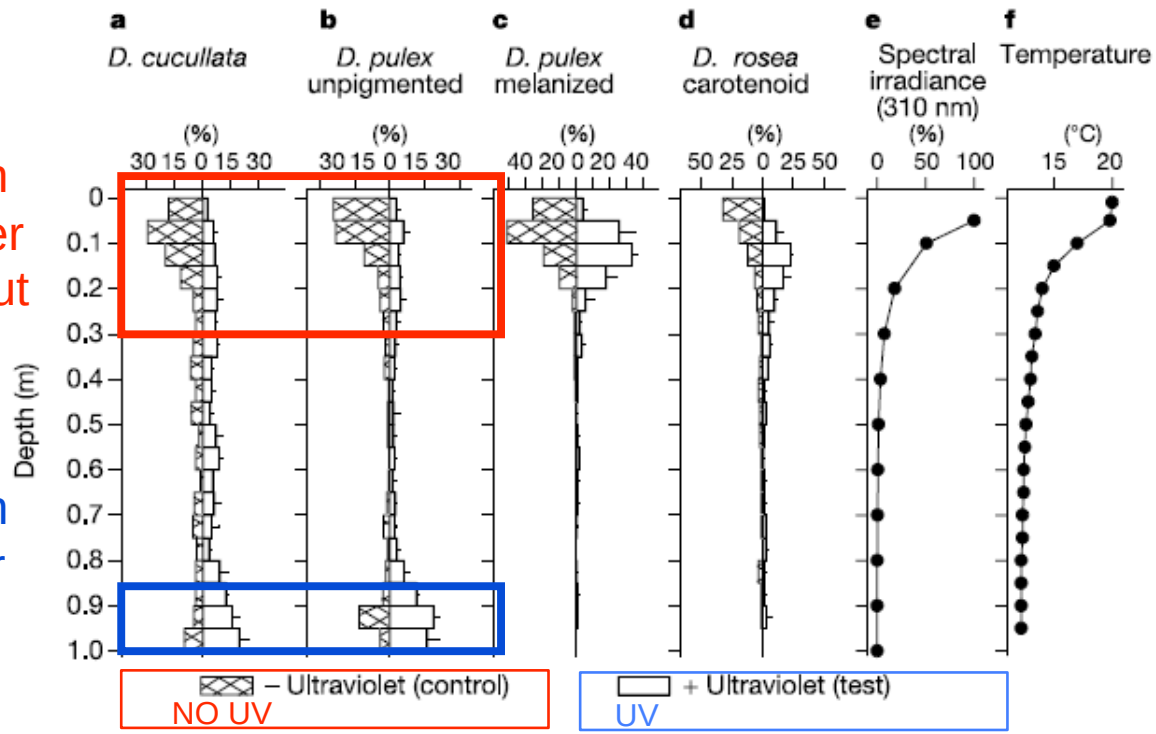



**Figure 2** Results from laboratory experiments. **a–d**, Vertical distribution of unpigmented *D. cucullata* (**a**) and *D. pulex* (**b**); melanized *D. pulex* (**c**); and *D. rosea* with carotenoids (**d**), in mesocosms (height 1 m; diameter 46 mm). **e**, **f**, We measured the vertical gradient of radiation (**e**) and the vertical temperature gradient (**f**). Data represent means of three replicates (± 1 s.d.) taken as the mean of five repeated measurements. Measured values of depth distribution in all experiments showed a significantly deeper position of daphnids in ultraviolet treatments (Mann–Whitney *U*-test; $P < 0.0001$).

Rhode et al., 2001

# Physical environment

## Adaptations to low/no light: Animals

### Great Horned Owl

*Bubo virginianus*

lsb.syr.edu/projects/cyberzoo/greathornedowl.html

### Long-Eared Bat

*Myotis evotis*

www.inkart.net/art/wildlife_art/long_eared_bat/long_eared_bat_art.htm

### Deep sea anglerfish

*Melanocetus johnsonii*


www.mbayaq.org/efc/living_species/default.asp?inhab=169

# Physical environment

## Species variability in temperature optimum

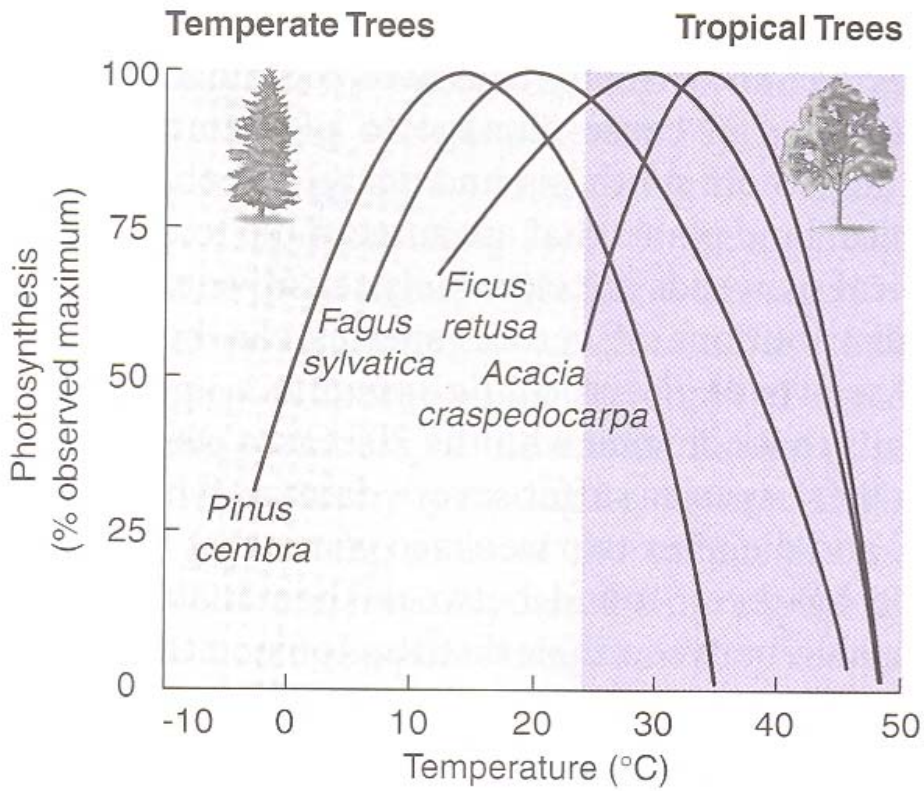



**FIGURE 3.3** The relationship between temperature and rate of photosynthesis (after Larcher, 1969; Kramer and Kozlowski, 1979).

# Physical environment

## $C_4$ species better adapted to higher temperatures

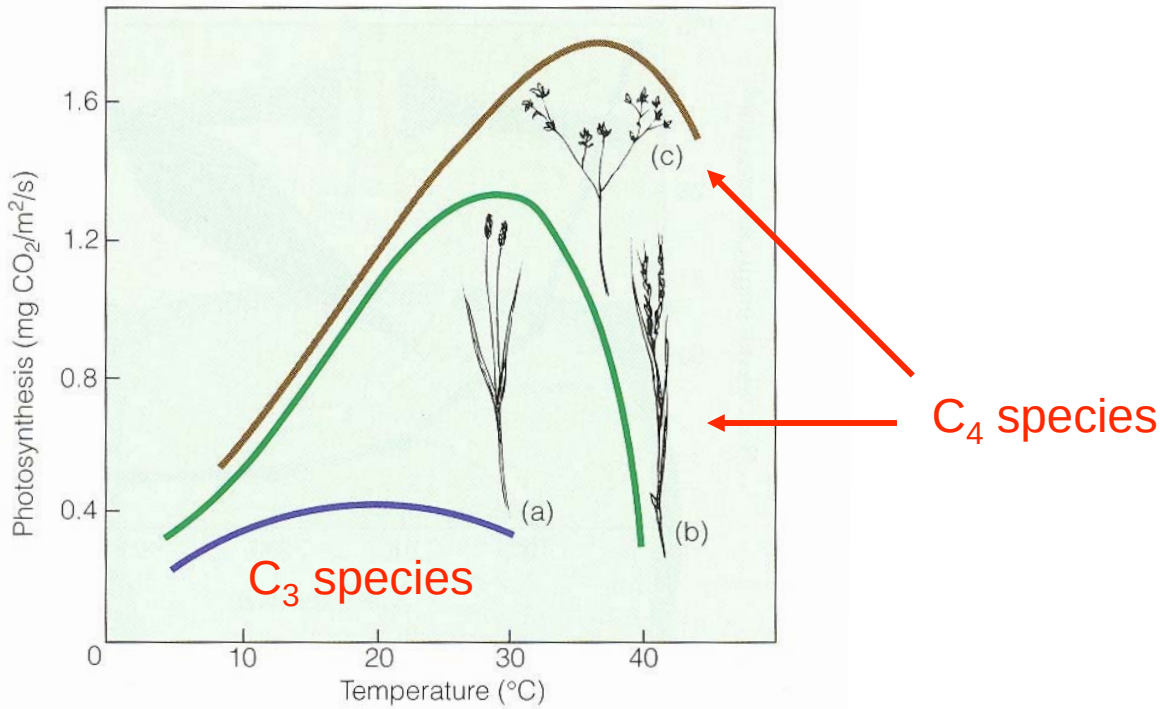



**Figure 6.21** | The effect of change in leaf temperature on the photosynthetic rates of $C_3$ and $C_4$ plants. **(a)** A $C_3$ plant, the north temperate grass *Sesleria caerulea*, exhibits a decline in the rate of photosynthesis as the temperature of the leaf increases. **(b)** A $C_4$ north temperate grass, *Spartina anglica*. **(c)** A $C_4$ shrub of the North American hot desert, *Tidestromia oblongifolia* (Arizona honeysweet). Note that the maximum rate of photosynthesis for the $C_4$ species occurs at higher temperatures than for the $C_3$ species. (Adapted from Bjorkman 1973.)

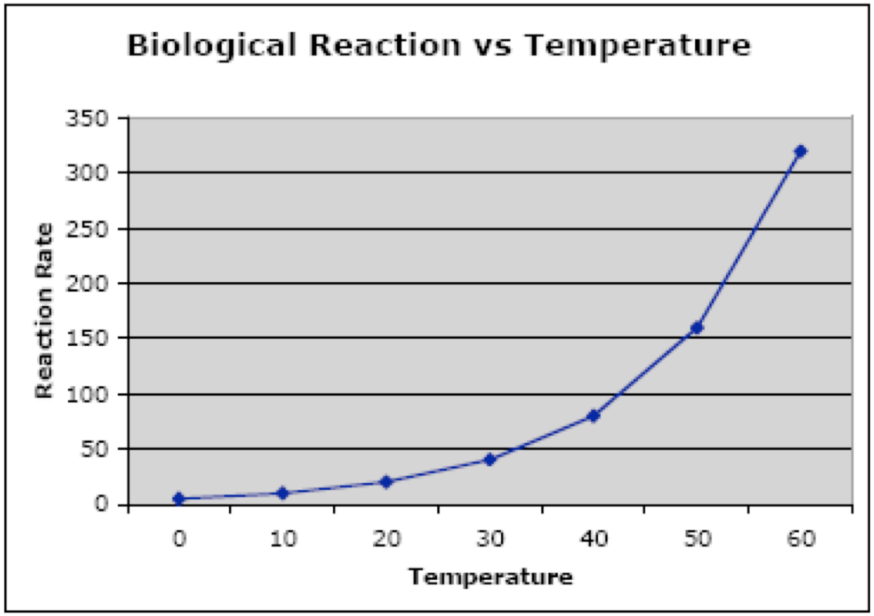
Smith and Smith, 2006

# Physical environment

## Temperature effects on respiration/metabolism

$$Q10 = R(t)/R(t-10)$$

most biological processes have a Q10 of 2-3 (i.e., they double or triple with each 10 degree increase)




Slide courtesy C. Still

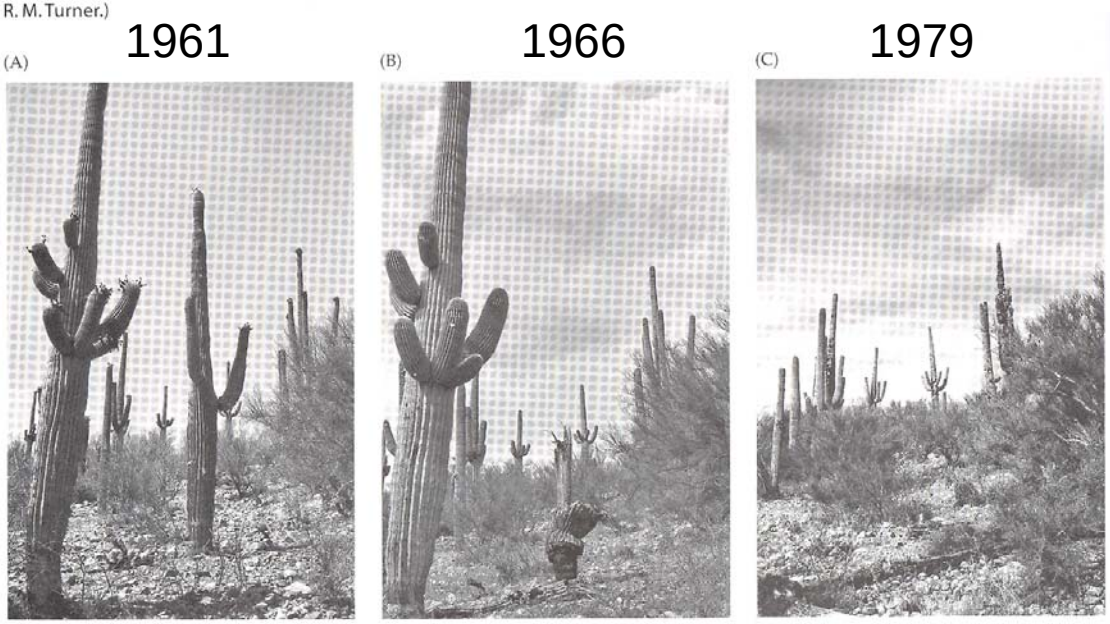
# Physical environment

## Temperature and the saguaro cactus (*Carnegiea gigantea)*

**FIGURE 4.19** Matched photographs of a stand of saguaro cacti near Redington, Arizona, near the upper elevational and northern edge of the species' range. (A) In 1961. (B) In 1966, showing the loss of one large individual (center foreground) and scars (white patches near tips of arms) on several other cacti as a result of severe frost in 1962. (C) In 1979, showing much additional mortality due to severe frosts in 1971 and 1978; several of the individual cacti still standing are dead or dying. (A and B courtesy of J. R. Hastings; C courtesy of R. M. Turner.)

Frost damage in 1962:

1961 1966 1979




0 deg C for >24 hours

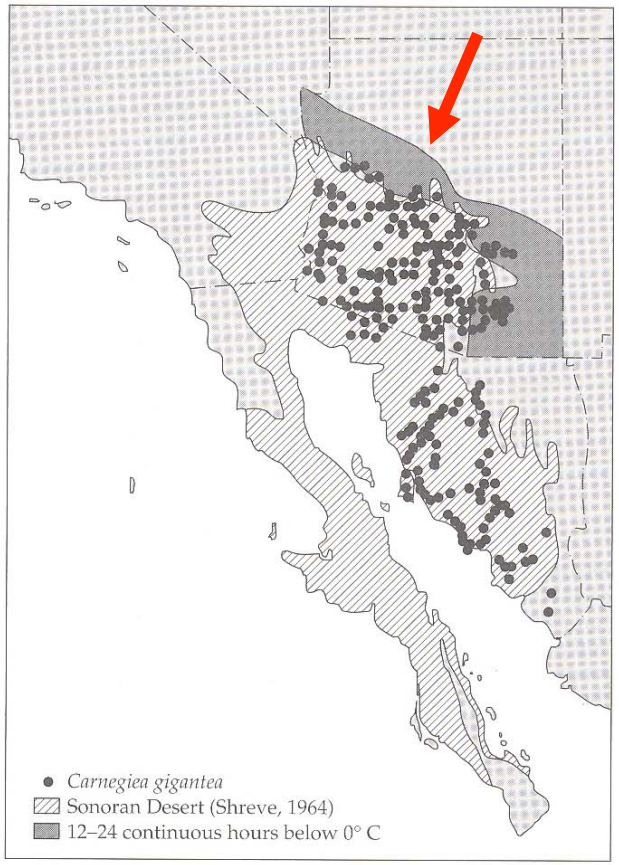


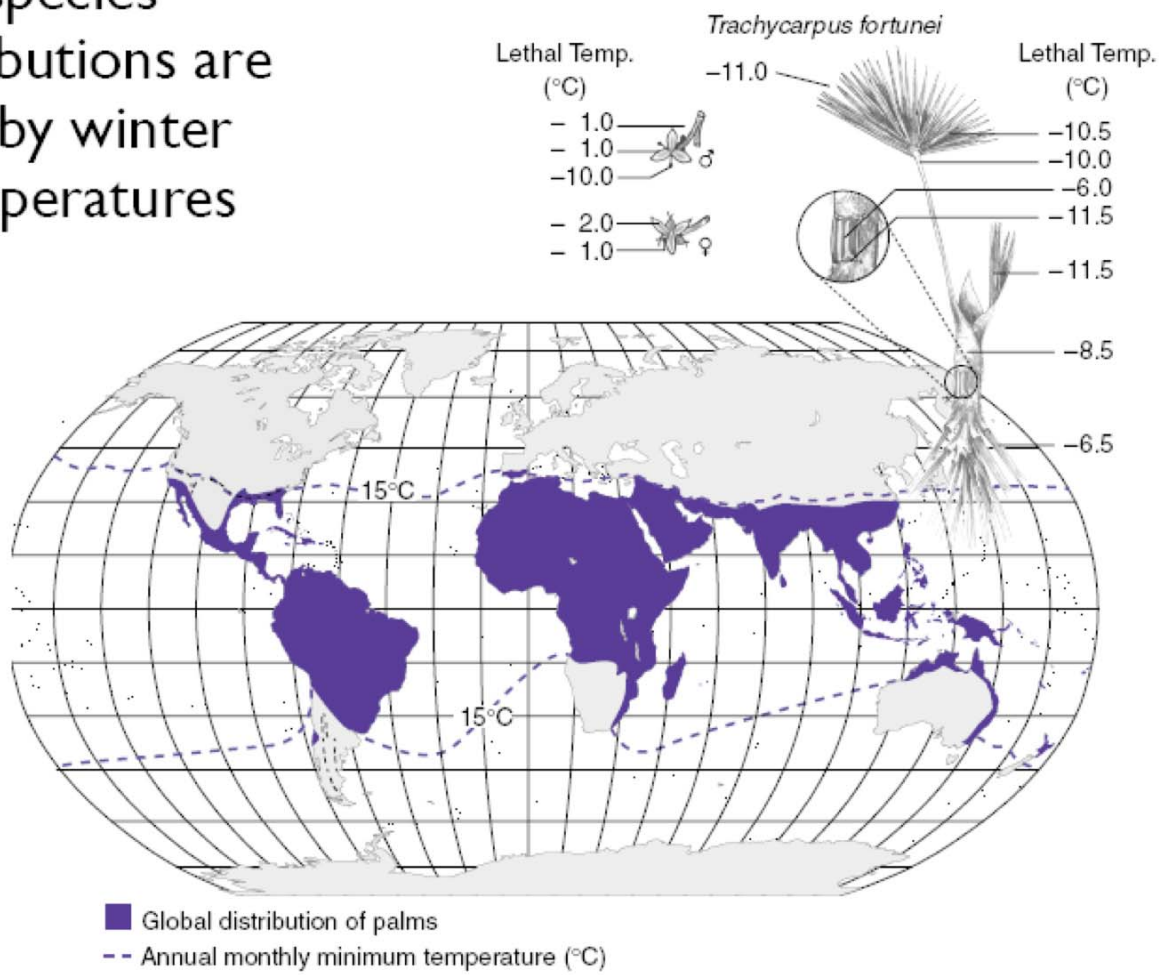

**FIGURE 4.18** Distribution of the saguaro cactus (*Carnegiea gigantea*) in relation to winter temperature regime. This cactus, like many other Sonoran Desert plants, is intolerant of prolonged freezing. Note the close correspondence between the northern limit of the saguaro, the northern boundary of the Sonoran Desert, and the region where temperatures remain below 0° C for more than 12 hours. (Data from Hastings and Turner 1965; Hastings et al. 1972).



Lomolino et al., 2006

# Physical environment

some plant species distributions are set by winter temperatures




Slide courtesy of C. Still

# Physical environment

other plant species distributions are set by summer temperatures and the length of the growing season

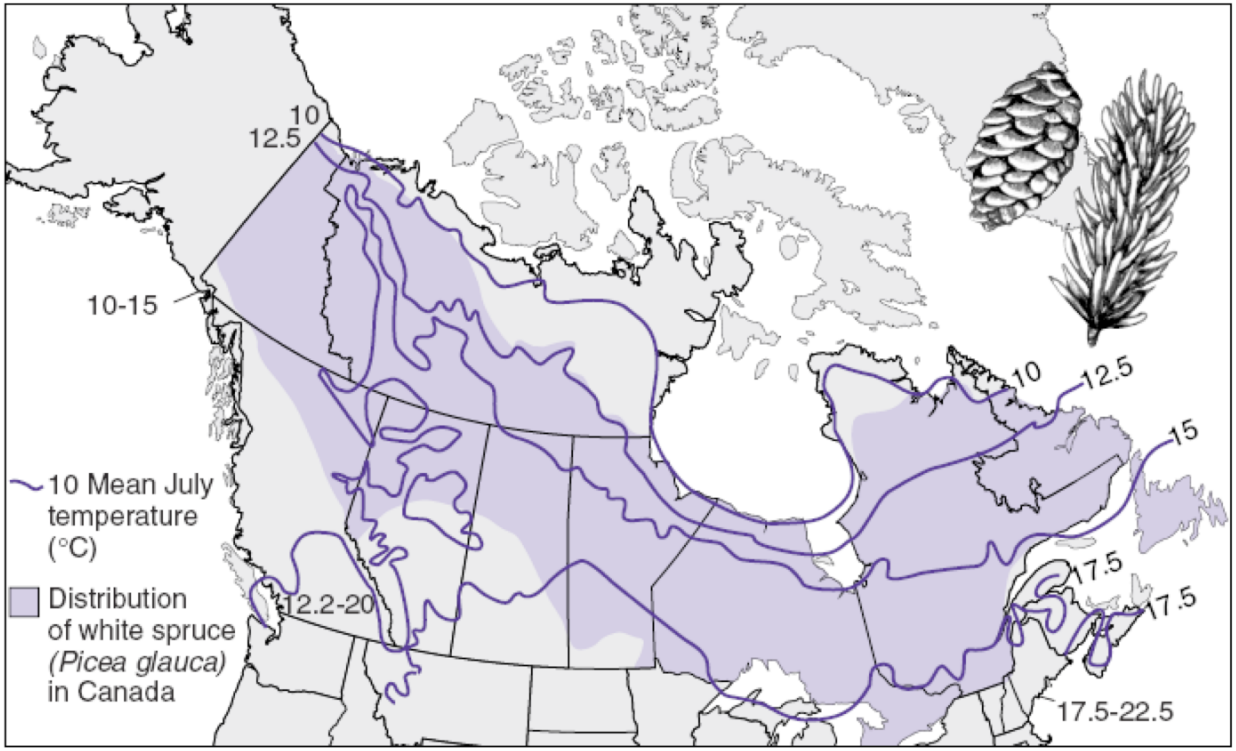


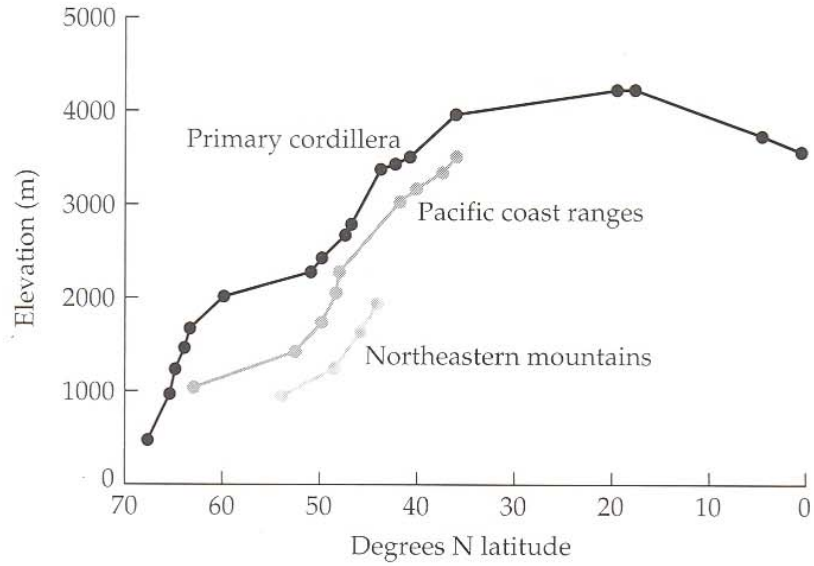

**FIGURE 3.4** The relationship between the northern limits of spruce and July temperatures in Canada.

Slide courtesy of C. Still

# Physical environment

# Latitude, elevation, and timberline

**FIGURE 4.20** Relationship of timberline to elevation and latitude in three different major mountain chains in North America. In general, timberline increases in elevation with decreasing latitude reflecting the influence of increasing temperature. Note, however, that the relationship is different in each mountain chain due to other factors such as length of the summer growing season. Note also that along the primary cordillera (chain extending from the northern Rocky Mountains to Panama) there is essentially no change in the elevation of timberline within the tropics and subtropics between about 35° N latitude and the equator. (After Daubenmire 1978.)



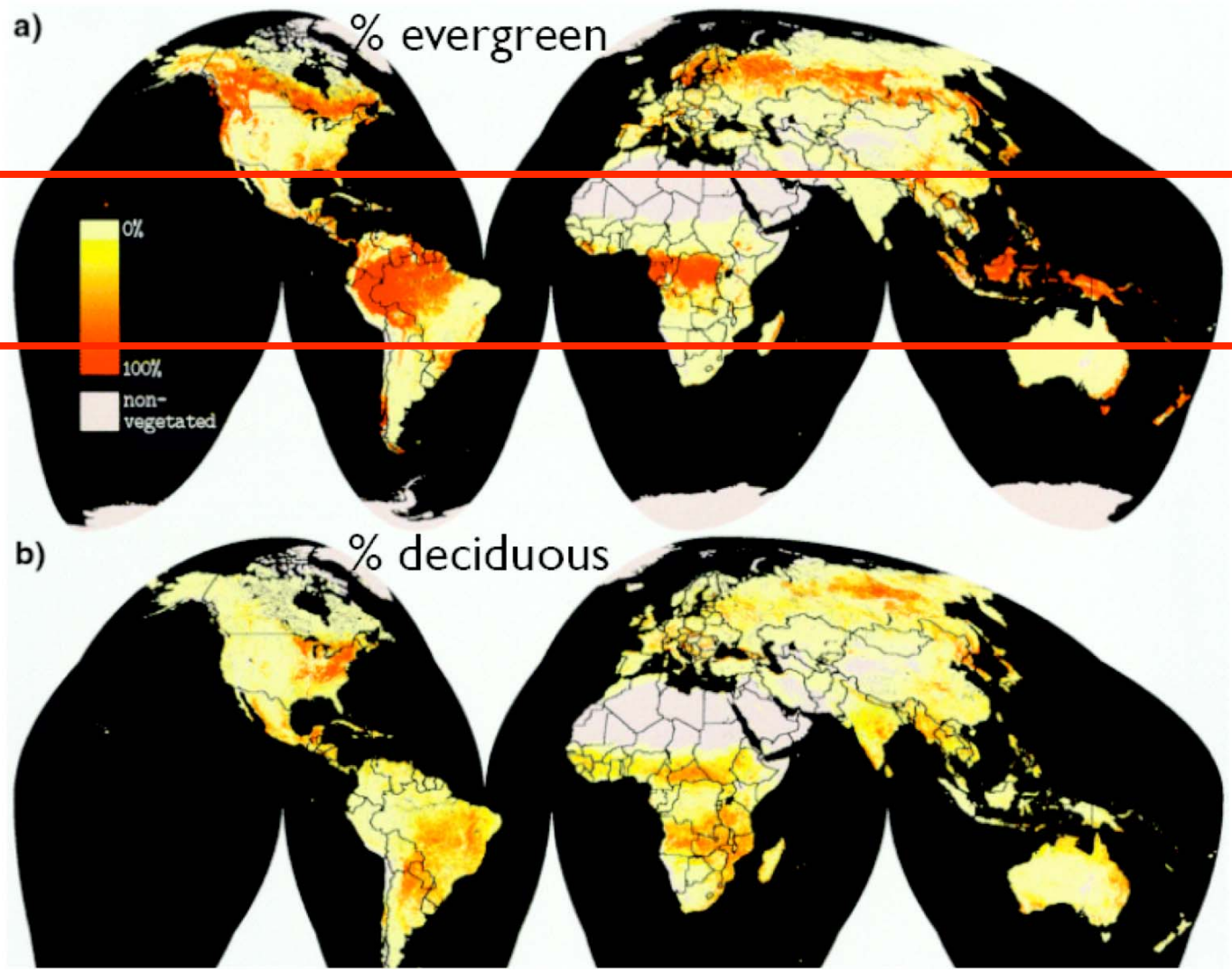

Lomolino et al., 2006

*What is the driving factor?*

# Physical environment

## Adaptations to cold: Deciduous broadleaf

Broadleaf

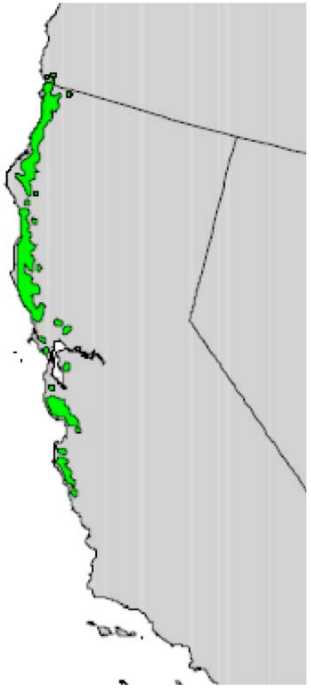



DeFries et al., 2000

# Physical environment

## But, not all conifers are resistant to cold, and not all deciduous trees are intolerant to cold

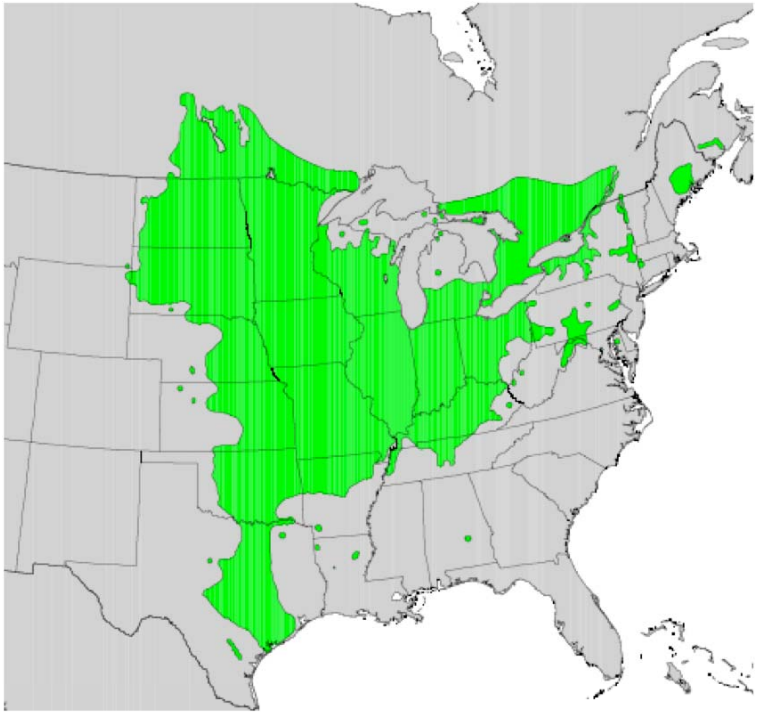
Redwood (*Sequoia sempervirens*)



Northern, upper elevation limit is -15 to -25 deg C

esp.cr.usgs.gov/data/atlas/little

Big-leafed (bur) oak (*Quercus macrocarpa*)



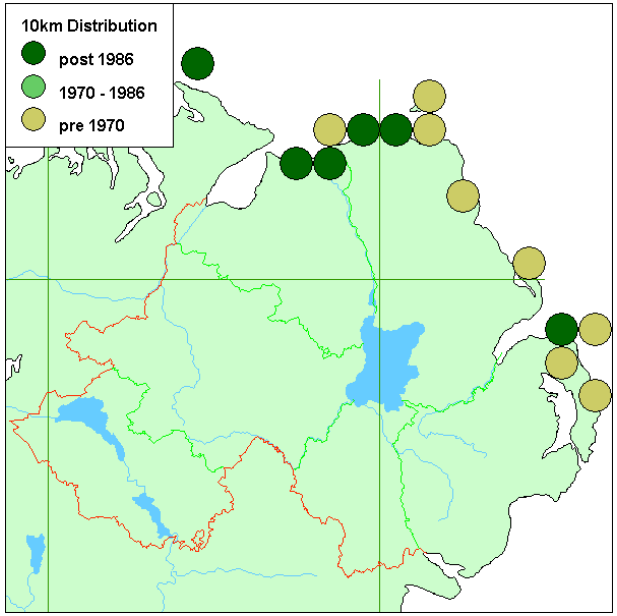
Can withstand -60 deg C

# Physical environment

## Southern range of many arctic plants governed by summer temperatures

Scots lovage:

- southern limit reached at 14.4 deg C
- plant adapted to shorter growing season
- higher respiration rates under warmer conditions and longer growing season => depletion of carbohydrate stores



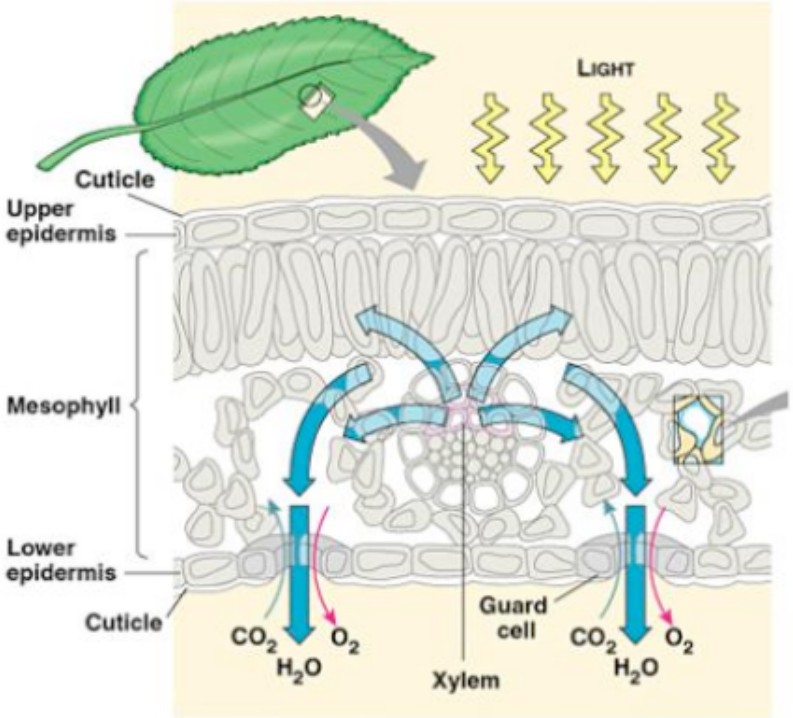

www.habitas.org.uk/flora/map.asp?item=3702

Ligusticum scoticum - Scots Lovage

www.s-weeds.net/familjer/apiaceae/liguscot.html

# Physical environment

## Transpiration – Evaporation of Water from Leaf Surfaces




Water from xylem enters air spaces of the leaf and also diffuses into mesophyll cells.

Water exits the leaf by diffusion mainly through stomata, which open and close in response to environmental and internal signals.

A small amount of water (<5%) can also diffuse through the epidermis.

Transpiration cools the leaf due to evaporative cooling.

Image credit: http://www.ualr.edu/~botany/transpiration.jpg

latent heat of evaporation = 2510 J/g at 0 °C

Slide courtesy C. Still

# Physical environment

## Body size versus metabolic rate

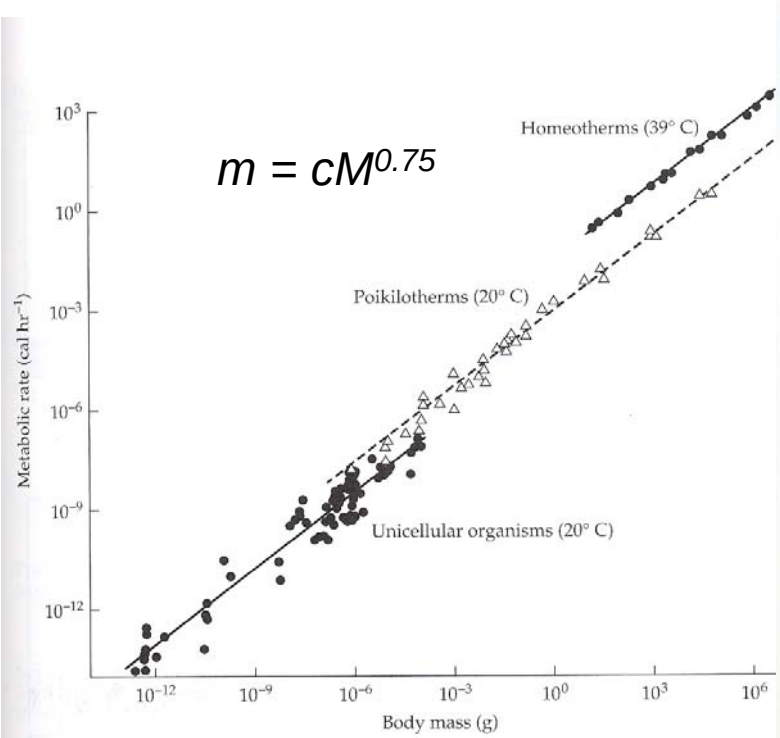



**FIGURE 5.2** Relationship between metabolic rate (m) and body mass (M) for a wide variety of organisms, ranging from unicellular forms to poikilothermic ("cold-blooded") animals to homeothermic birds and mammals. Note that the axes are on a logarithmic scale, so that the relationship is described by a power function of the form $m = cM^{0.75}$, where the constant (c) varies slightly among the three different groups, but the exponent or slope (0.75) is remarkably constant. (After Hemmingsen 1960.)

Lomolino et al., 2006

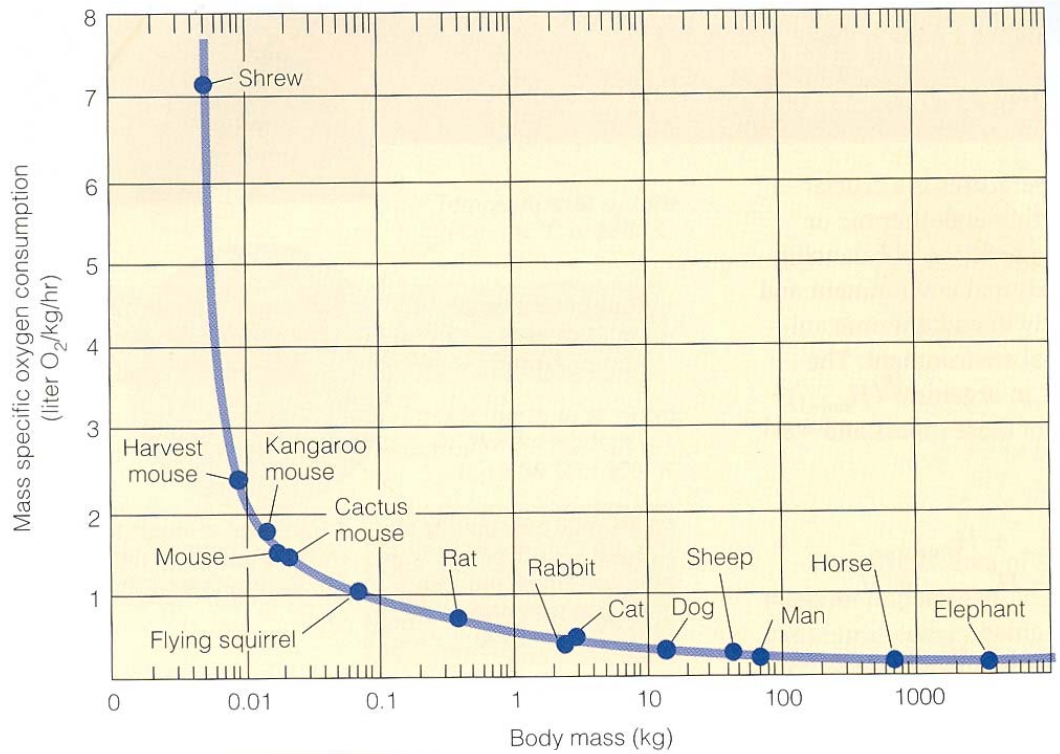



**Figure 7.14** | Observed relationship between metabolic rate (oxygen consumption) per unit body mass (mass-specific metabolic rate) and body mass for a variety of mammal species. Mass-specific metabolic rate increases with decreasing body mass. Note that body mass is plotted on a logarithmic scale. (Adapted from Schmidt-Nielson 1979.)

Smith and Smith, 2006

# Physical environment

## Temperature affects sex ratio of turtle hatchlings

Table 1. Sex ratios of hatchling turtles. The question mark indicates sex unknown: infertile, or dead at early stages.

| Sex | Experiment 1 | | Experiment 2 | | Experiment 3 | |
|---|---|---|---|---|---|---|
| | 25°C | 30.5°C | 20° to 30°C | 23° to 33°C | Shade (*13*) | Sun |
| | | | *Graptemys ouachitensis* | | | |
| Male | 210 | 0 | 73 | 0 | 100 | 4 |
| Female | 0 | 211 | 0 | 65 | 0 | 123 |
| ? | 23 | 26 | 38 | 44 | 101 | 74 |
| | | | *Graptemys pseudogeographica* | | | |
| Male | 173 | 4 | 43 | 0 | 35 | 1 |
| Female | 0 | 147 | 0 | 43 | 0 | 19 |
| ? | 49 | 81 | 20 | 24 | 10 | 25 |
| | | | *Graptemys geographica* | | | |
| Male | 98 | 0 | | | 37 | 0 |
| Female | 0 | 88 | | | 0 | 15 |
| ? | 24 | 31 | | | 12 | 36 |
| | | | *Chrysemys picta* | | | |
| Male | 81 | 0 | | | | |
| Female | 0 | 81 | | | | |
| ? | 21 | 20 | | | | |
| | | | *Trionyx spiniferus* | | | |
| Male | 33 | 27 | | | | |
| Female | 34 | 24 | | | | |
| ? | 16 | 35 | | | | |

*Implications of global warming?*

Bull and Vogt, 1979

# Physical environment

## *Animals: Temperature effects on distributions*

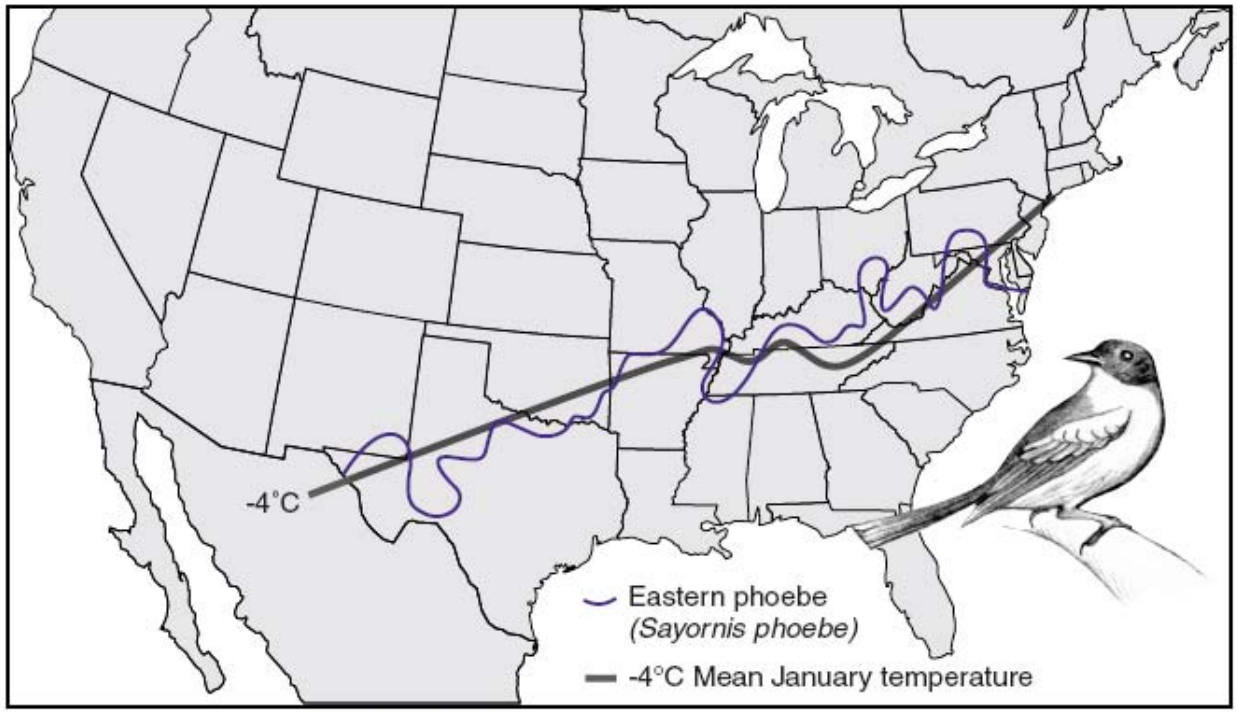



**FIGURE 3.8** The relation between January temperature and the northern limits of the eastern phoebe *(Sayornis phoebe)*. North of the –4° C January isotherm, the birds cannot obtain food in sufficient quantities to support the metabolic activity required to maintain their body temperature above lethal levels (after Root, 1993).

# Physical environment

Animal behavior adaptations

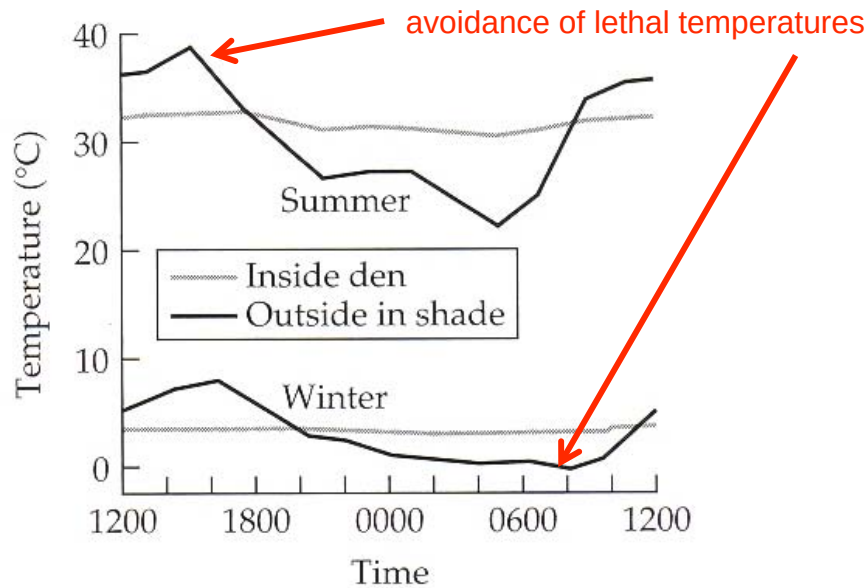



**FIGURE 3.18** Temperatures inside and outside the den of a bushy-tailed woodrat (*Neotoma cinerea*) and a deep crack between large boulders in the high desert of southeastern Utah during midsummer and midwinter. Because the den (where the animal spends most of its time) experiences much less variation than the macroclimate outside, it affords vital protection from stressfully high and low temperatures in summer and winter, respectively. (After Brown 1968.)

Lomolino et al. 2006

# Physical environment

## Animals: Temperature adaptations to cold

### *Fur/fat*

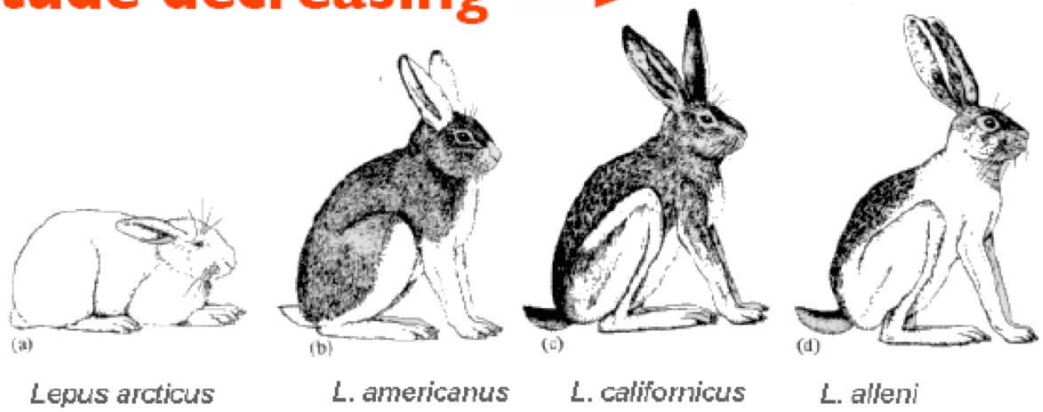
www.alumniexhibits.com/illustration.html

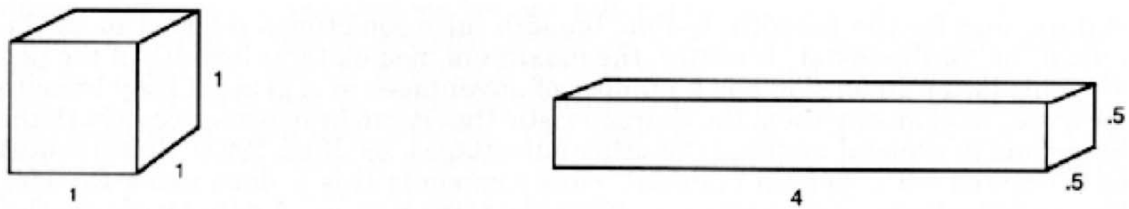
users.tmok.com/~yak/

# Physical environment

Allen's Rule - the length of extremities like ears and arms decreases with temperature

**latitude decreasing →**




| | |
|---|---|
| mass = 1 | mass = 1 |
| surface area = 6 | surface area = 8.5 |
| **surface area/mass = 6** | **surface area/mass = 8.5** |

Illustration ofAllen's Rule from Ruff (1994:71)

Figure credit: http://www.mun.ca/biology/scarr/Lepus_variation.gif

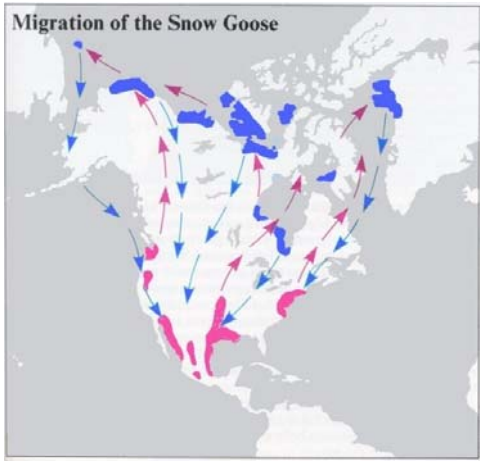
Slide courtesy C. Still

# Physical environment

## Animals: Temperature adaptations to cold

### *Migration*

North-south




www.paulnoll.com/Oregon/Birds/Avian-migration.html

Higher-lower

www.oregonzoo.org/Cards/Cascades/elk.roosevelt.htm

# Physical environment

## Animals: Temperature adaptations to cold

### *Physiology*

Cold hardening of mountain pine beetle

Decrease of supercooling point as winter progresses

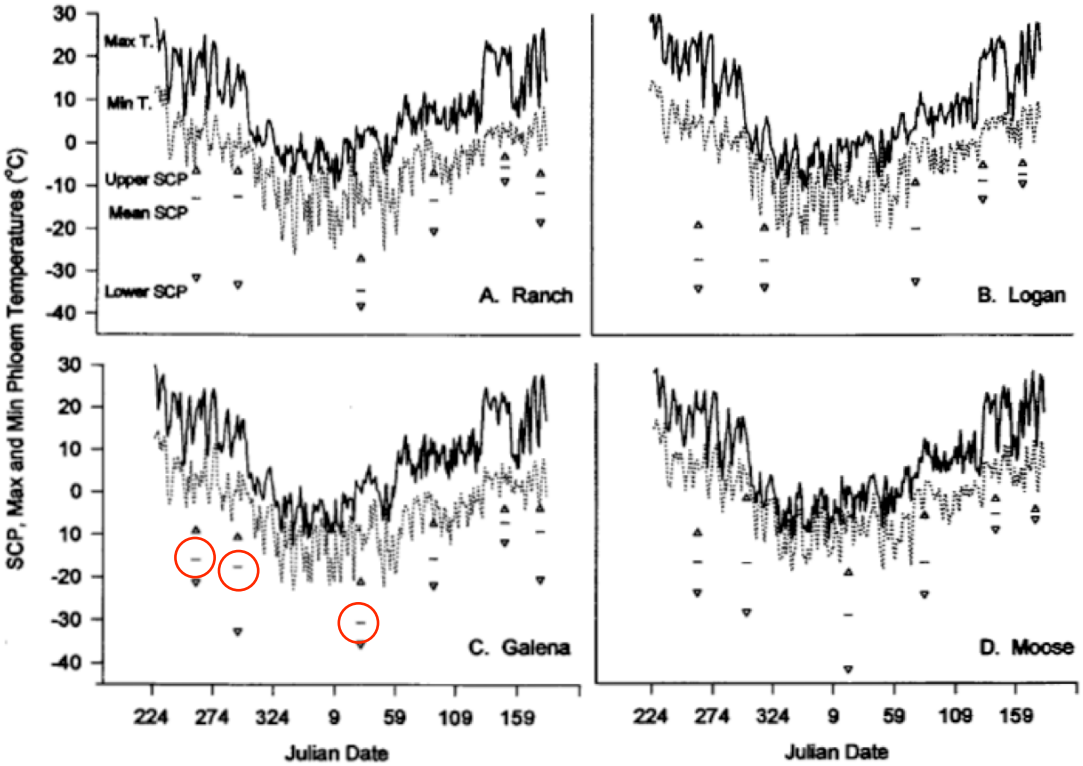


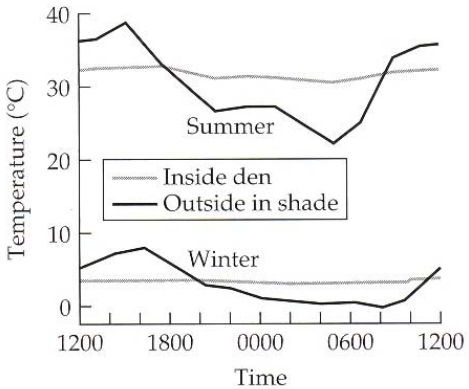

Fig. 1. Maximum and minimum phloem temperatures (T, °C) at 4 sites (A–D) in 1992–1993 with the mean (—) and range (△, ▽) of associated larval supercooling points (SCP) (°C).

Bentz and Mullins, 1999

# Physical environment

## Animals: Temperature adaptations to heat

### *Shelter*

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Lomolino et al. 2006


homepages.gac.edu/~cjgroh/classes/TZPictures.html

# Physical environment

## Water temperature and distribution (fish)

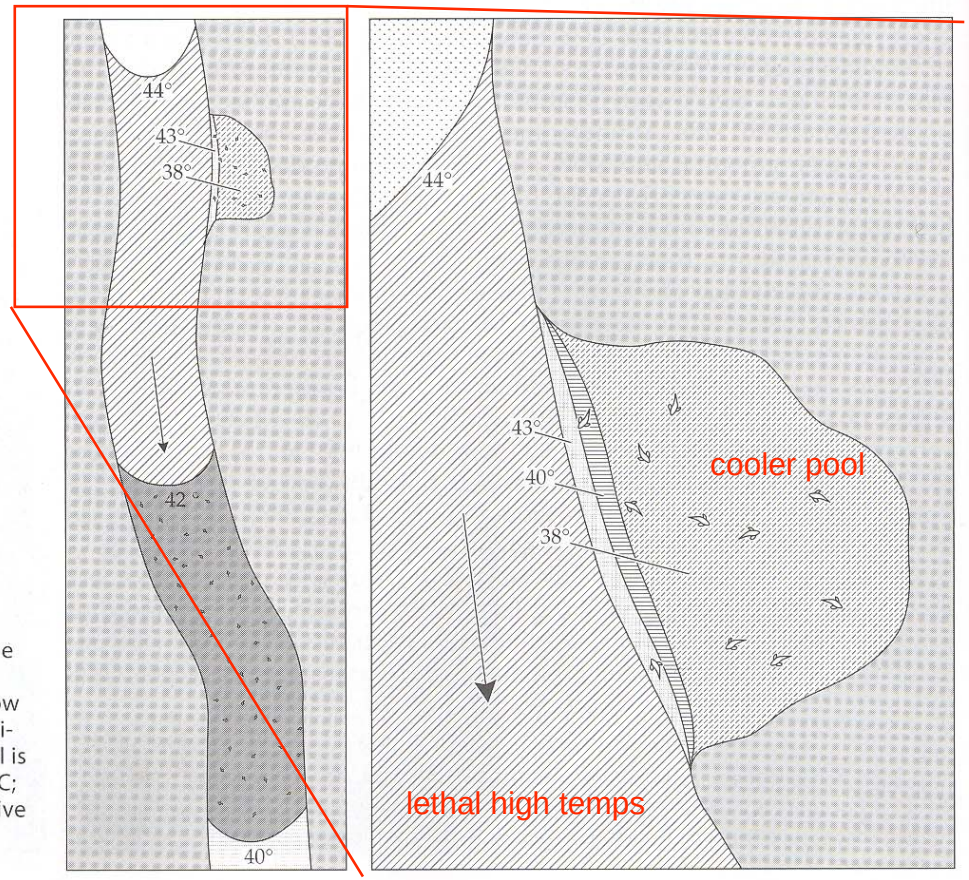


**FIGURE 4.22** Temperature limits the local distribution of a desert pupfish (*Cyprinodon nevadensis*) in the outflow of a hot spring near Death Valley, California. The fast-flowing main channel is above the lethal temperature of 43° C; fish are trapped, but are able to survive in the cooler side pool (enlarged at right). (After Brown 1971c.)

Lomolino et al. 2006

# Physical environment

## Animals: Temperature adaptations to heat

### *Morphology*

"Cool" adaptations to hot conditions

Elephant (*Loxodonta africana*)

fohn.net/elephant-pictures-facts

Chameleons (*Chamaeleo*)

www.african-safari-journals.com/chameleon-pictures.html

# Physical environment

## Animals: Temperature adaptations to heat

### *Sweating/panting/licking*

www.vet.ed.ac.uk/animalpain/Pages /images/Optimised%20Images/optphotos /EQsweating.jpg

www.junglewalk.com/photos /Lion-pictures-I2287.htm

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