# Section 3:
# Mechanisms of influence: Basic ecology

Learning outcomes

After this section, you should be able to:

- understand the mechanisms by which temperature and moisture influence plants and animals
- describe adaptations of plants and animals that allow them to live in suboptimal environments



## Environmental Gradients
### Different plants have different climate factors

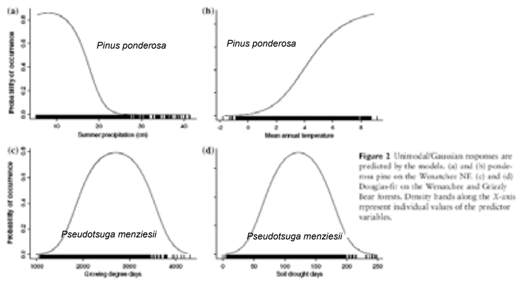



Figure 2 Unimodal/Gaussian responses are predicted by the models. (a) and (b) ponderosa pine on the Wenatchee NF. (c) and (d) Douglas-fir on the Wenatchee and Grizzly Bear forests. Density bands along the X-axis represent individual values of the predictor variables.

McKenzie et al., 2003



## Environmental Gradients
### Range and density

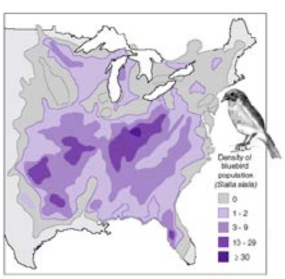
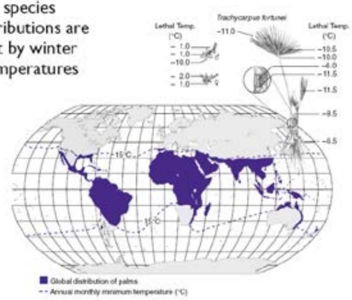



FIGURE 3.12 The range and population density of eastern Bluebird (Sialia sialis) in North America. Notice how population density is greatest in patches near the center of the geographic range (after Bystrak, 1979 and Brown and Gibson, 1983).

## Temperature

some plant species distributions are set by winter temperatures




Slide courtesy of C. Still

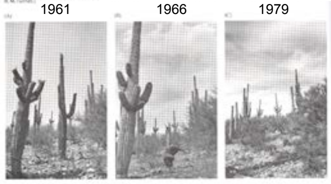


## Temperature

Temperature and the saguaro cactus (*Carnegiea gigantea)*

Frost damage in 1962:

1961 1966 1979



0 deg C for >24 hours

Lomolino et al., 2006



## Temperature

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

## Temperature

*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).



## Temperature

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



## Temperature

Animals: Temperature adaptations to cold

*Physiology*

Cold hardening of mountain pine beetle

Decrease of supercooling point as winter progresses

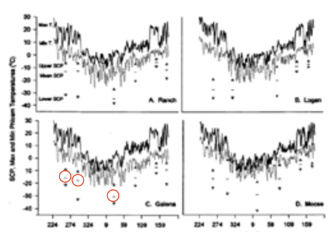



Fig. 1. Maximum and minimum phloem temperatures (T, °C) at 4 sites (A–D) in 1992–1993 with the mean (—) and range (Δ, ∇) of associated larval supercooling points (SCP) (°C).

Bentz and Mullins, 1999

## Temperature

### Animals: Temperature adaptations to heat

*Shelter*

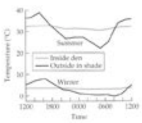



**FIGURE 3.18** Temperatures inside and outside the den of a bushy-tailed woodrat (*Neotoma cinerea*) and a deep crack between large boulders in the high desert of southeastern Utah during midsummer and midwinter. Because the den (where the animal spends most of its time) experiences much less variation 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


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



## Temperature

### 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



## Temperature

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 (JJ) | 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 | | | | |

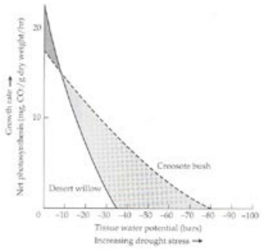
*Implications of global warming?*

Bull and Vogt, 1979

## Moisture

Soil moisture controls on woody plants in desert Southwest

FIGURE 4.23 Trade-offs between growth rate and drought tolerance in two species of desert shrubs: creosote bush (*Larrea tridentata*), which grows in some of the driest North American deserts; and desert willow (*Chilopsis linearis*), which has an overlapping geographic range, but is more mesophytic, occurring in microhabitats along watercourses where the soil is permanently moist. Note that under relatively high drought stress (light gray region) creosote bush has the higher net photosynthetic rate and is able to grow faster, shade, and competitively exclude desert willow. (After Odening et al. 1974.)




Lomolino et al. 2006



## Moisture

Moisture stress on plants: mortality

Croplands

http://soilcrop.tamu.edu/photogallery/cornsorghum+/images/drought%20stress%203.jpg

Pinyon pine in SW

*Photo by Craig Allen - USGS*



## Moisture

Soil moisture controls on tree species distribution in PNW

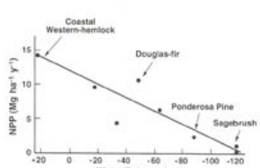



Figure 18.15. The water balance and aboveground net primary productivity (ANPP) of ecosystems in the Pacific Northwest. The relationship between water balance and ANPP emphasizes the idea that increases in water availability along climatic gradients in mountainous regions relate to an increase in net primary productivity. (After Gholz, 1982. Reprinted with permission of the Ecological Society of America.)

Barnes et al., 1998

## Moisture

Rooting depth in arid landscape controls species distribution

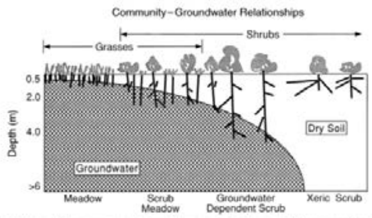


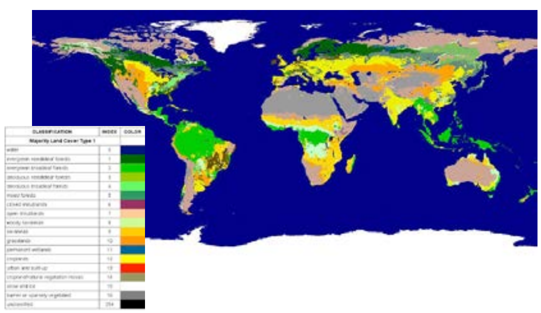

FIG. 2. Phreatophytic plant communities in Owens Valley are distributed on the landscape according to patterns of groundwater availability. Meadow communities require shallow water tables, a mixture of shrubs and grasses occur at intermediate water table depths, and shrubs dominate the deepest levels. Xeric shrub communities, as defined here, require no groundwater resources. Exotic annuals can compete with varying success at any point on this gradient.

Elmore et al., 2003

Climate Change Ecology 16 Prof. J. Hicke

## Moisture

Controls of soil moisture at larger scale



Friedl et al.

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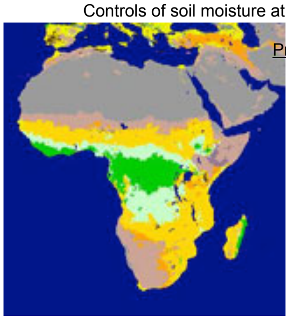
## Moisture

Controls of soil moisture at larger scale



| Precip | Biomass | Veg type |
|---|---|---|
| dry | none | none |
| | | shrublands |
| | | savannas |
| wet | high | dense forest |
| dry | none | |

Friedl et al.

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## Moisture

Plant strategies to deal with drought: 1. Escapees

- Perennials (dormancy)
- Annuals ("emphemerals")

Still very dry and nothing is blooming yet, photo from Anza Borrego Desert State Park on Jan. 1, 2007

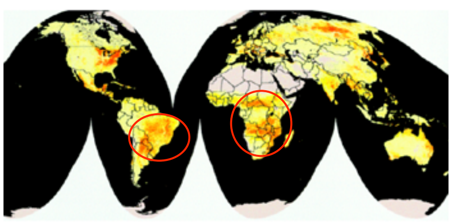
www.desertusa.com/wildflo/wildupdates.html



## Moisture

Plant strategies to deal with drought: 2. Avoiders

another strategy: shed leaves (drought deciduous)
focus on subtropical forests with high % deciduous



Slide courtesy C. Still

DeFries et al., 2000



## Moisture

Plant strategies to deal with drought: 2. Avoiders

store water in the trunk
(up to 120,000 liters!)

http://www.safari-tours.com/pgbs/images/lodges/baobab.jpg

have deep roots (*Larrea tridentata* roots measured to 53 m!)


Slide courtesy C. Still

## Moisture

### Adaptations to low water availability

Namib Desert beetle (*Onymacris unguicularis*)

morphology adaptations to capture fog:
- bumps on back
- channels to mouth
- head down behavior

can capture 40% of body weight in one morning

www.nacoma.org.na/Pictures/Photos/Beetle.jpg

http://www.biomechanics.bio.uci.edu/_html/nh_biomech/namib/beetle.htm



## Multiple factors/interactions

What factors limit white spruce at its northern and southern extent?

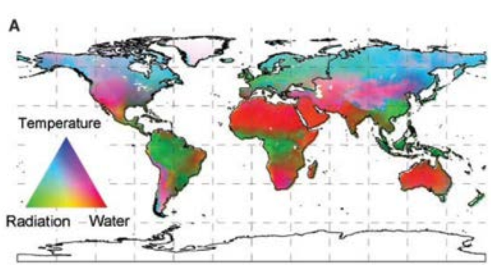
Summer temperatures

Moisture stress (high summer temps, low precip)



## Multiple factors/interactions

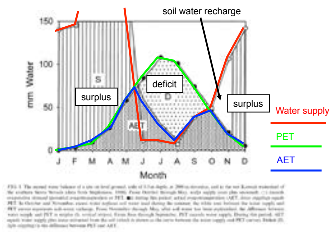
*Controls on Net Primary Production*




Nemani et al., 2003

## Annual water balance and climatic water deficit

Sierra Nevada, CA: Coniferous

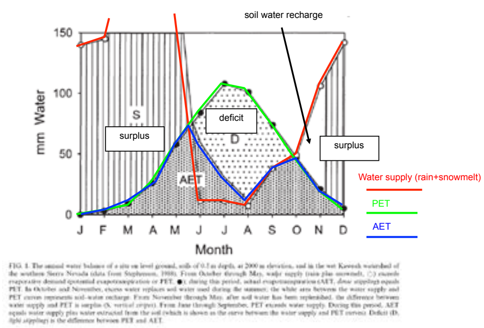



Stephenson, 1998



## Annual water balance and climatic water deficit

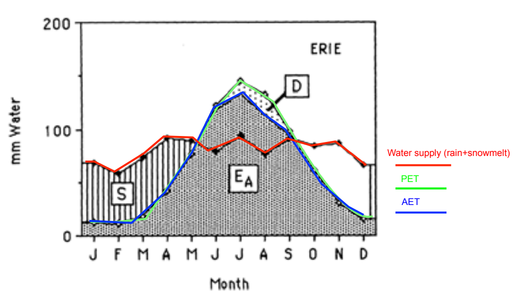
Sierra Nevada, CA: Coniferous



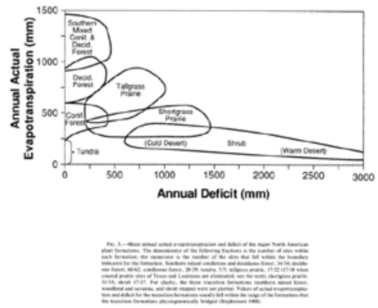

 Stephenson, 1998 

## Annual water balance and climatic water deficit

Erie, PA: Deciduous



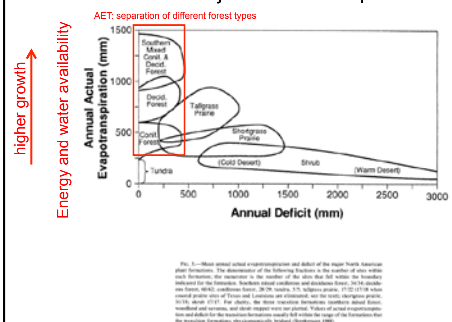
## Multiple factors/interactions
Distribution of major N. America plant formations




Stephenson, 1990



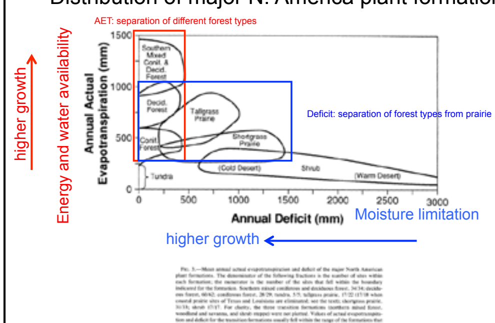
## Multiple factors/interactions
Distribution of major N. America plant formations




Stephenson, 1990

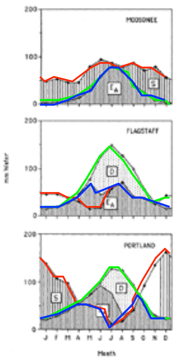


## Multiple factors/interactions
Distribution of major N. America plant formations




Stephenson, 1990

## Multiple factors/interactions




Three reasons conifers dominate over deciduous trees

energy limited: low PET => low AET/growth

Precipitation
PET
AET

water limited: low precip => low AET/growth

S = surplus of water (hatched)
D = deficit of water (stippled)

asynchrony in energy, water supplies => low AET/growth

FIG. 4.—The water balances of three North American localities supporting coniferous forest (data from Eagleman 1976). Annual actual evapotranspiration ($E_A$, *dense stippling*) is less than 600 mm because of energy limitation (Moosonee, Ont.), water limitation (Flagstaff, Ariz.), or asynchronous timing of the energy and water supplies (Portland, Oreg.). See figure 1 for a further explanation of water-balance diagrams. *Solid diamonds*, precipitation; *open diamonds*, potential evapotranspiration.

Stephenson, 1990