

# Ecology

**Study of interactions between organisms and environment**

Organisms  
Populations  
Communities  
Ecosystems  
Landscapes  
Global

Increasing scale and complexity

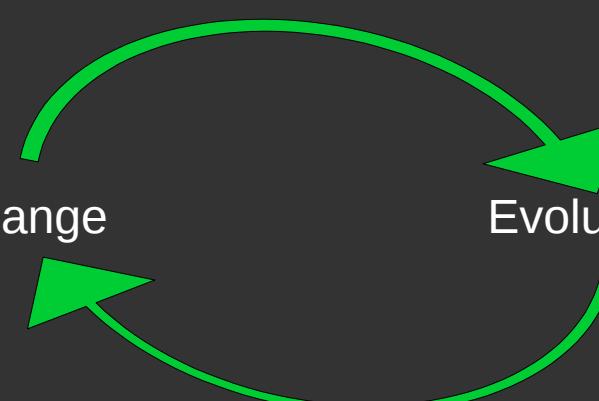
Climate

Biomes

Ecological change

Evolutionary change

Controllers of species' distributions



# What is an “environment?”

# What is an “environment?”

## Abiotic

Temperature  
Rainfall  
Seasonality  
Drought frequency  
pH  
Cation exchange capacity  
Prevailing wind direction  
Altitude  
Base mineral composition  
Radiation  
Salinity  
Depth  
Tidal difference  
Aerosol density  
Pressure (air or water)  
 $\text{CO}_2$  concentration

Etc. etc. etc.....

## Biotic

Bacterial exudates  
Secondary compounds  
Food web complexity  
Net primary production  
C turnover rate  
Predator / Prey  
Competition  
Symbionts  
Genetic expression  
Phenotypic plasticity  
Priority effects  
Pathogens  
Viral evolution rates  
Humans (strong effects)  
Density effects  
Dormancy

Etc. etc. etc... ....

# Organismal Ecology

How an organism interacts with it's biotic and abiotic environment



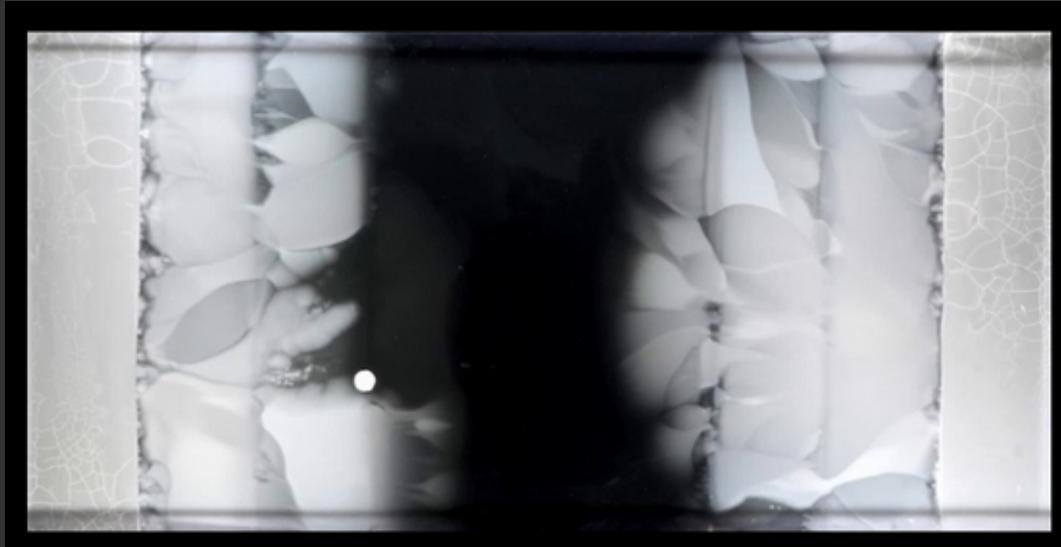
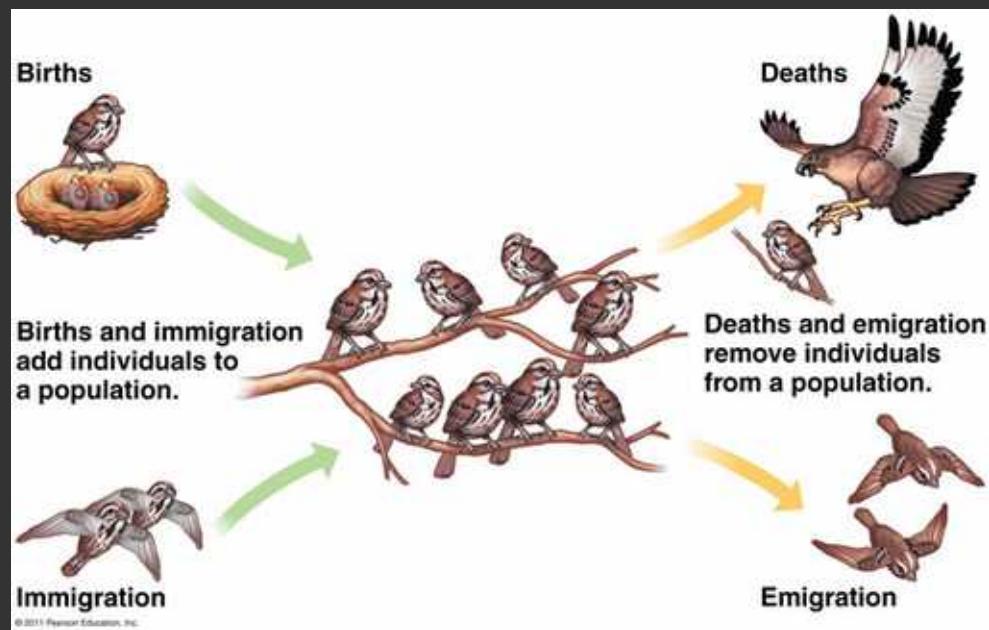
# Organismal Ecology

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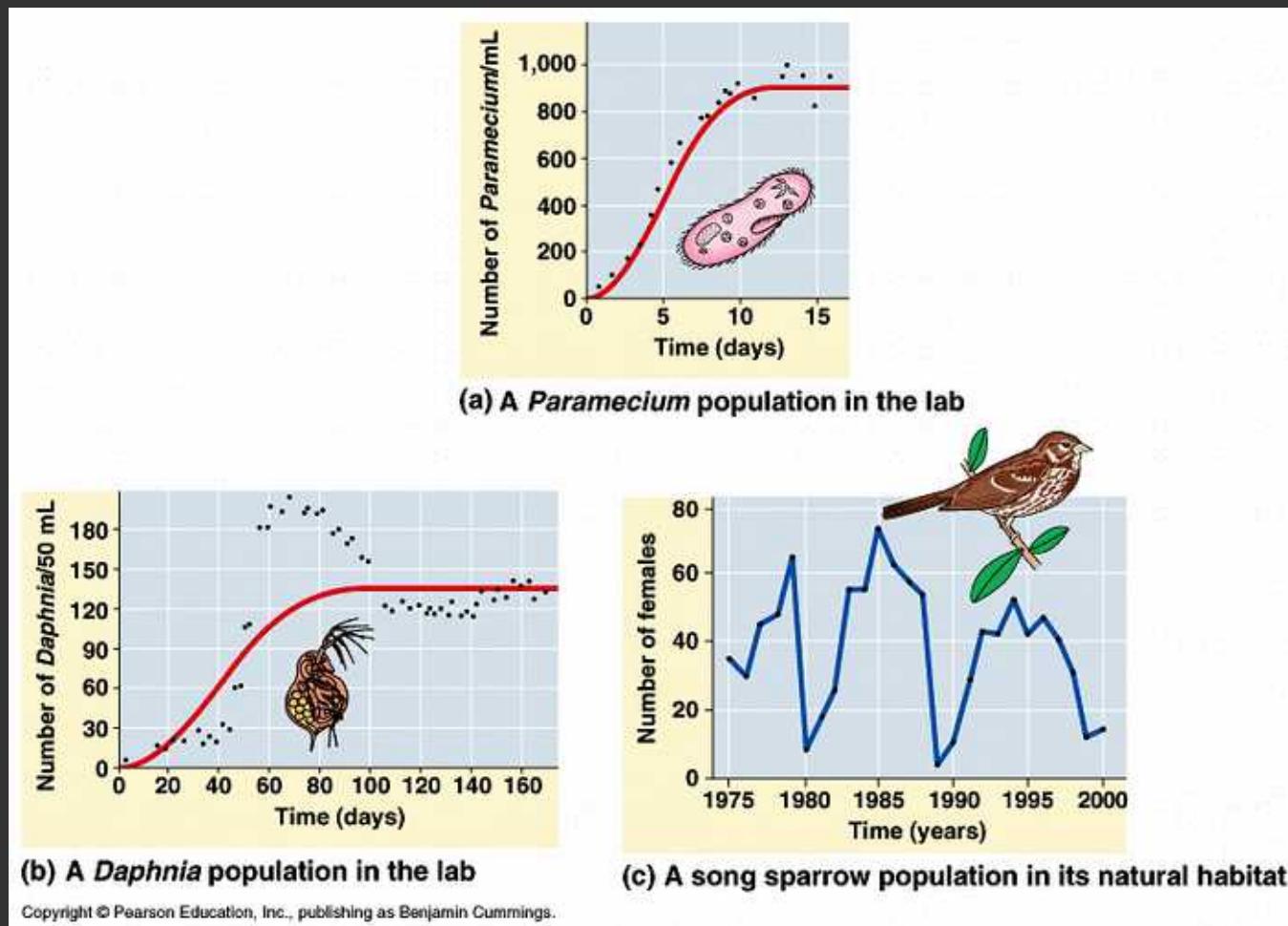
# Population Ecology

Factors that affect changes in population size, fitness, allele frequencies, distribution  
Etc.



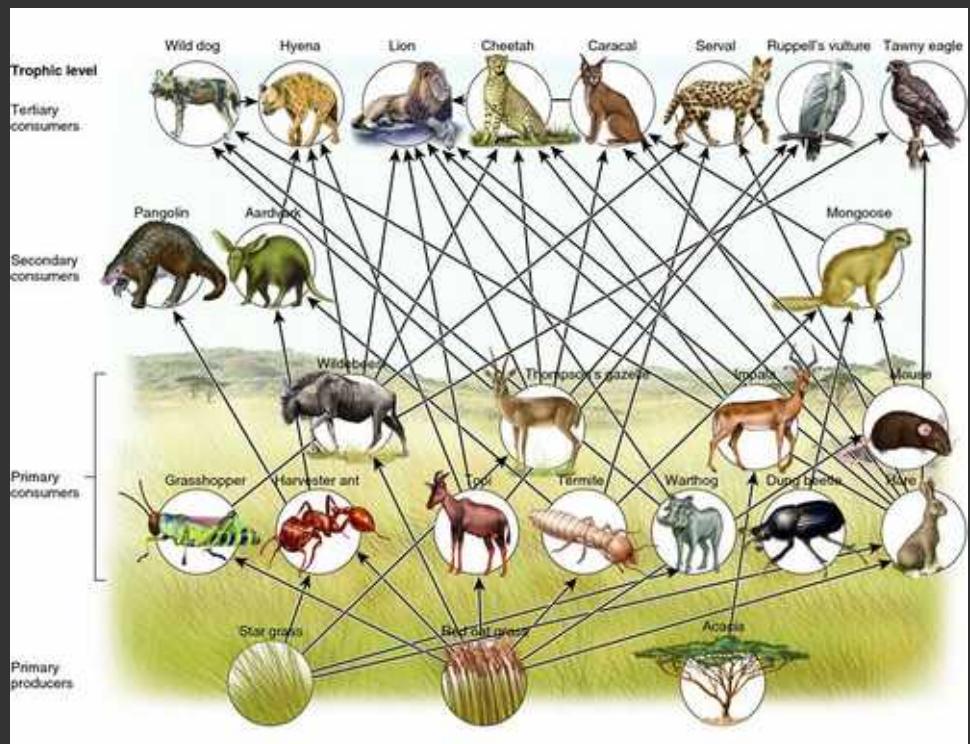
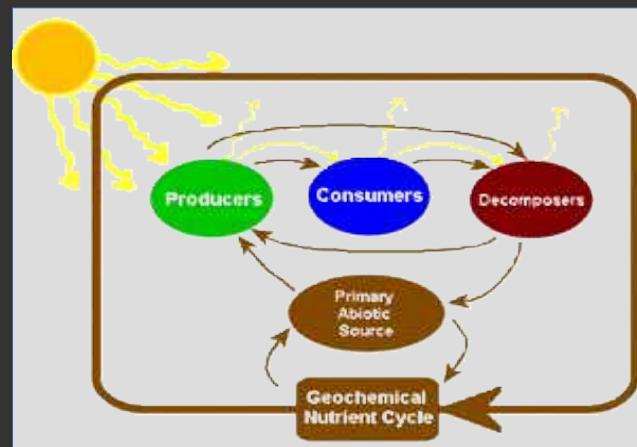
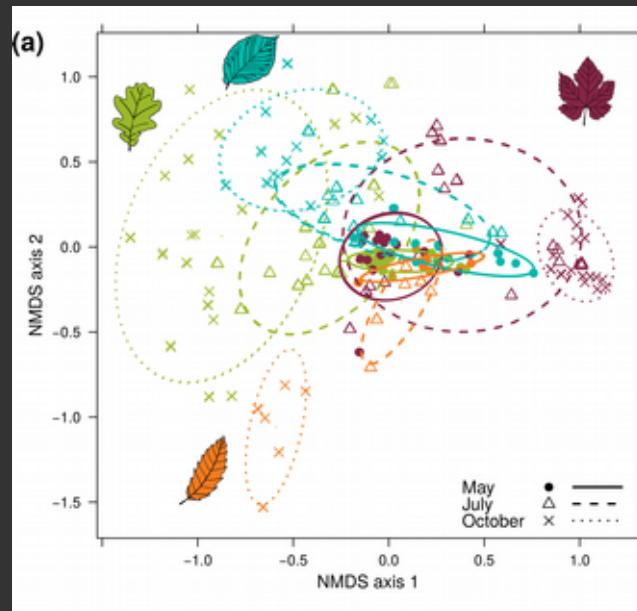
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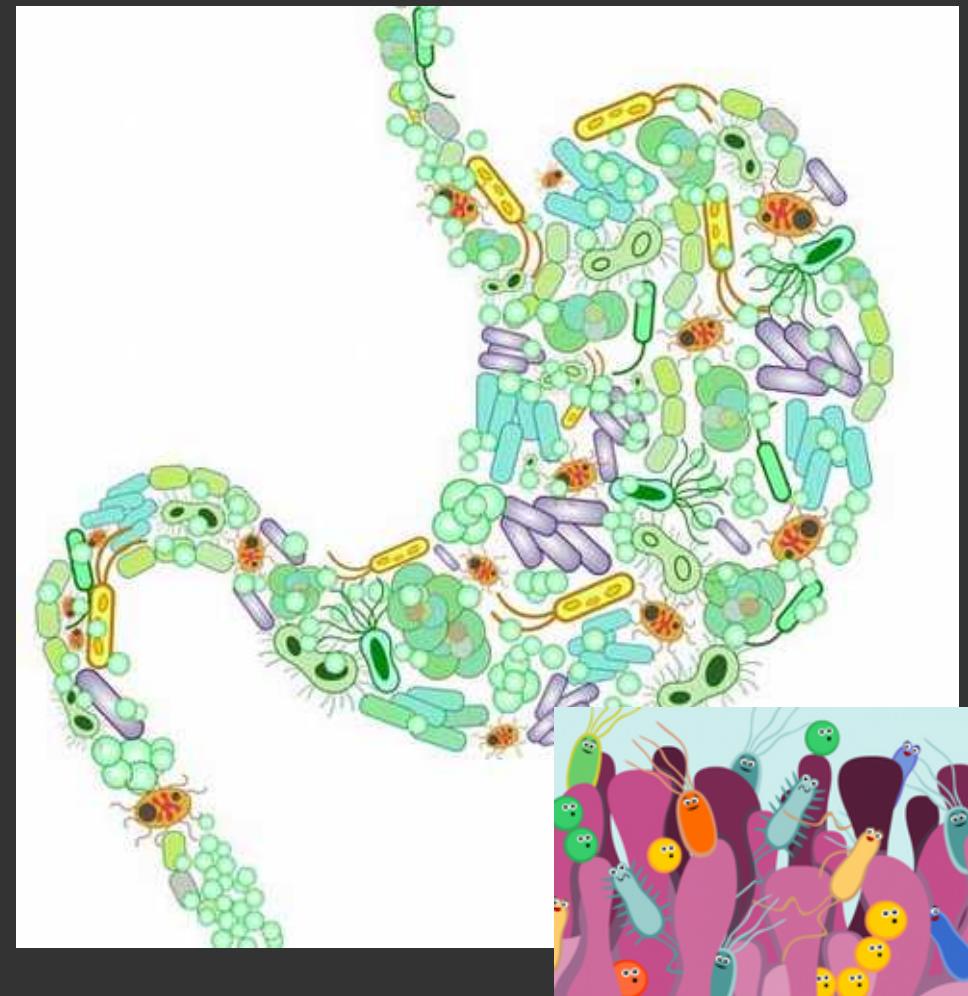
# Community Ecology

Interactions between different species, and factors that shape community formation and fate



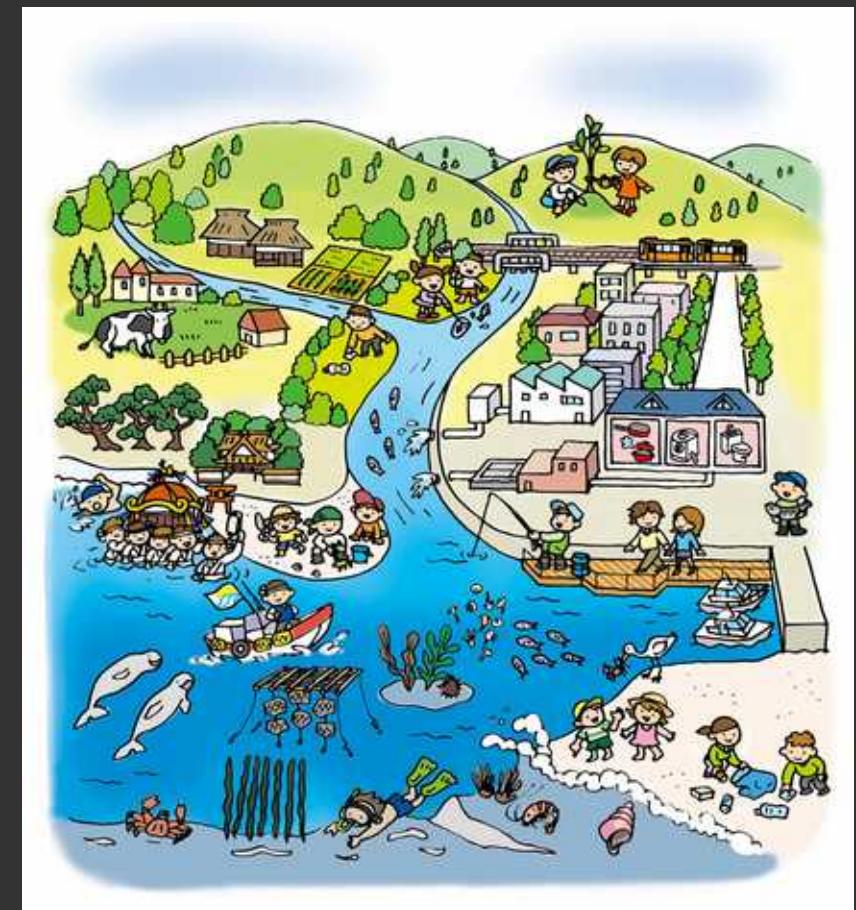
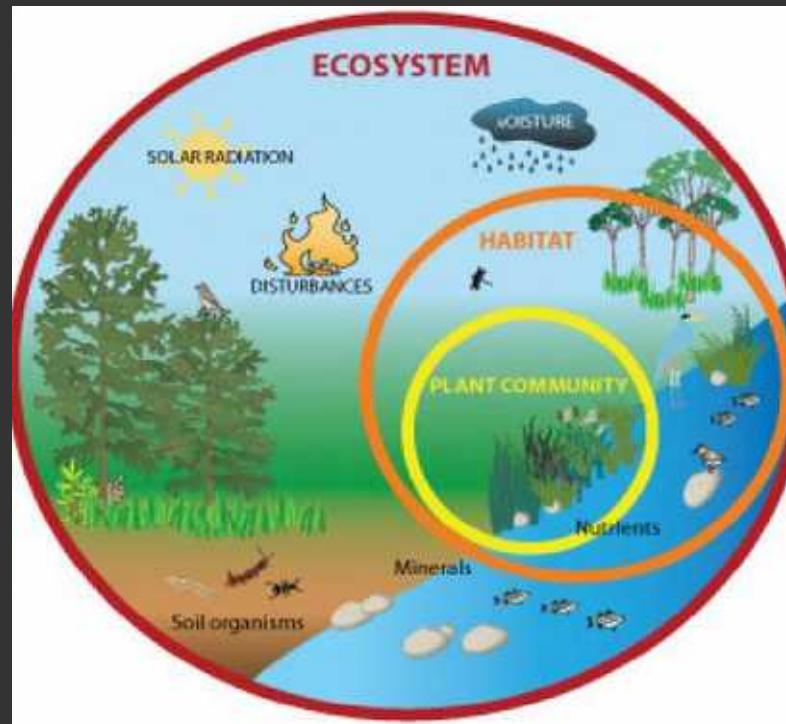
# Community Ecology

Interactions between different species, and factors that shape community formation and fate



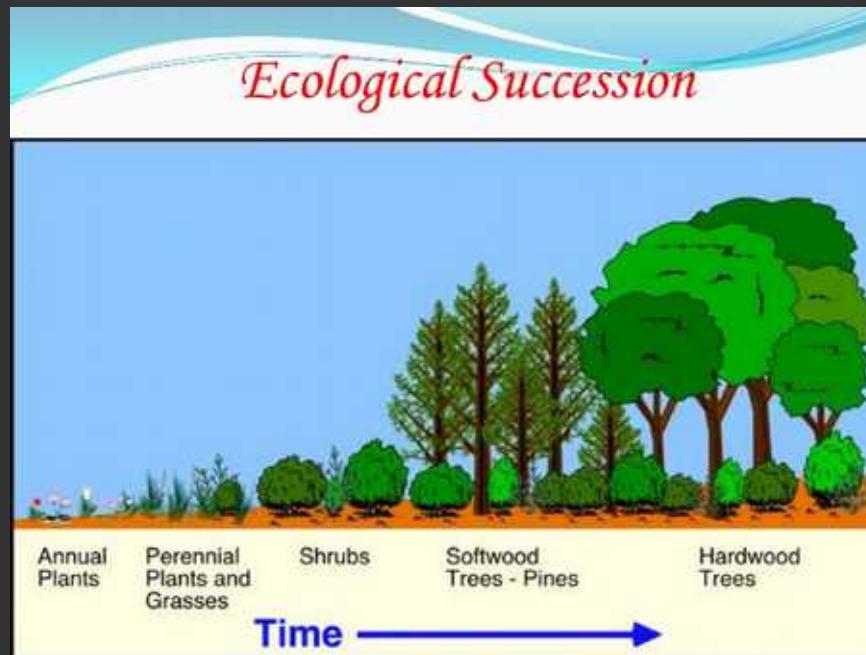
# Ecosystem Ecology

Flow of energy and elements between populations and communities and environment at ecosystem scale



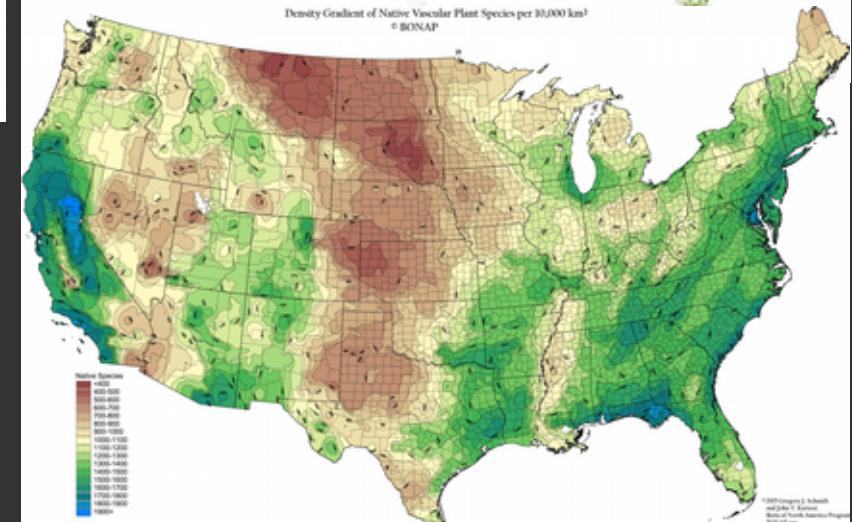
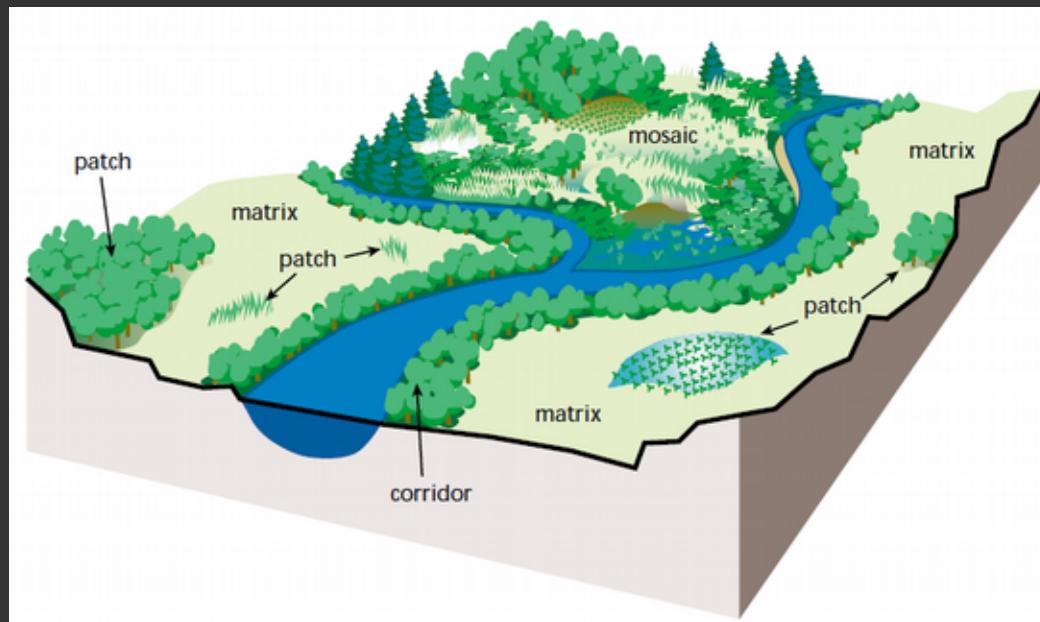
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Flow of energy and elements between populations and communities and environment at ecosystem scale



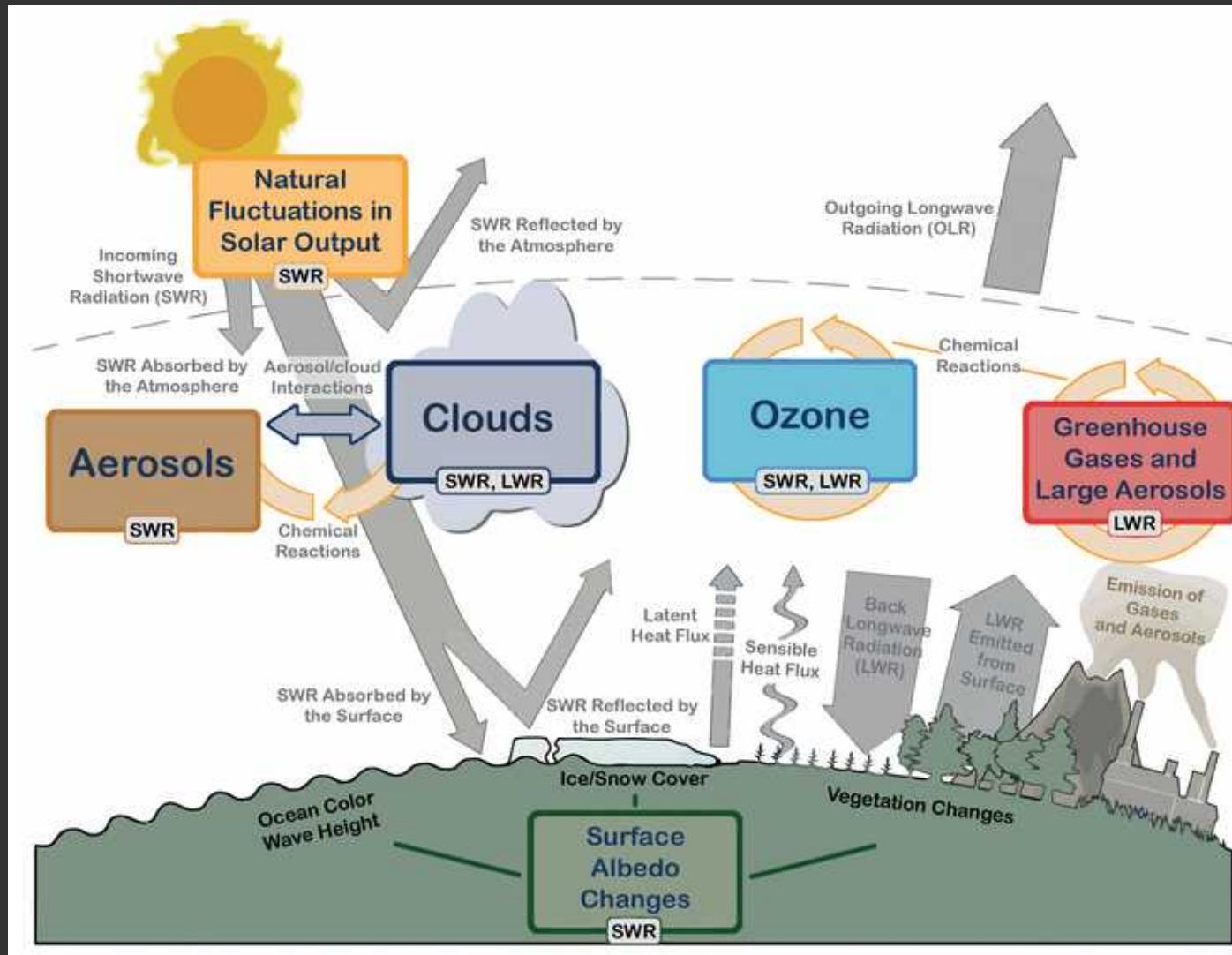
# Landscape Ecology

Flow of energy and elements between populations and communities and environment at landscape scale (multiple adjoining ecosystems)



# Global Ecology

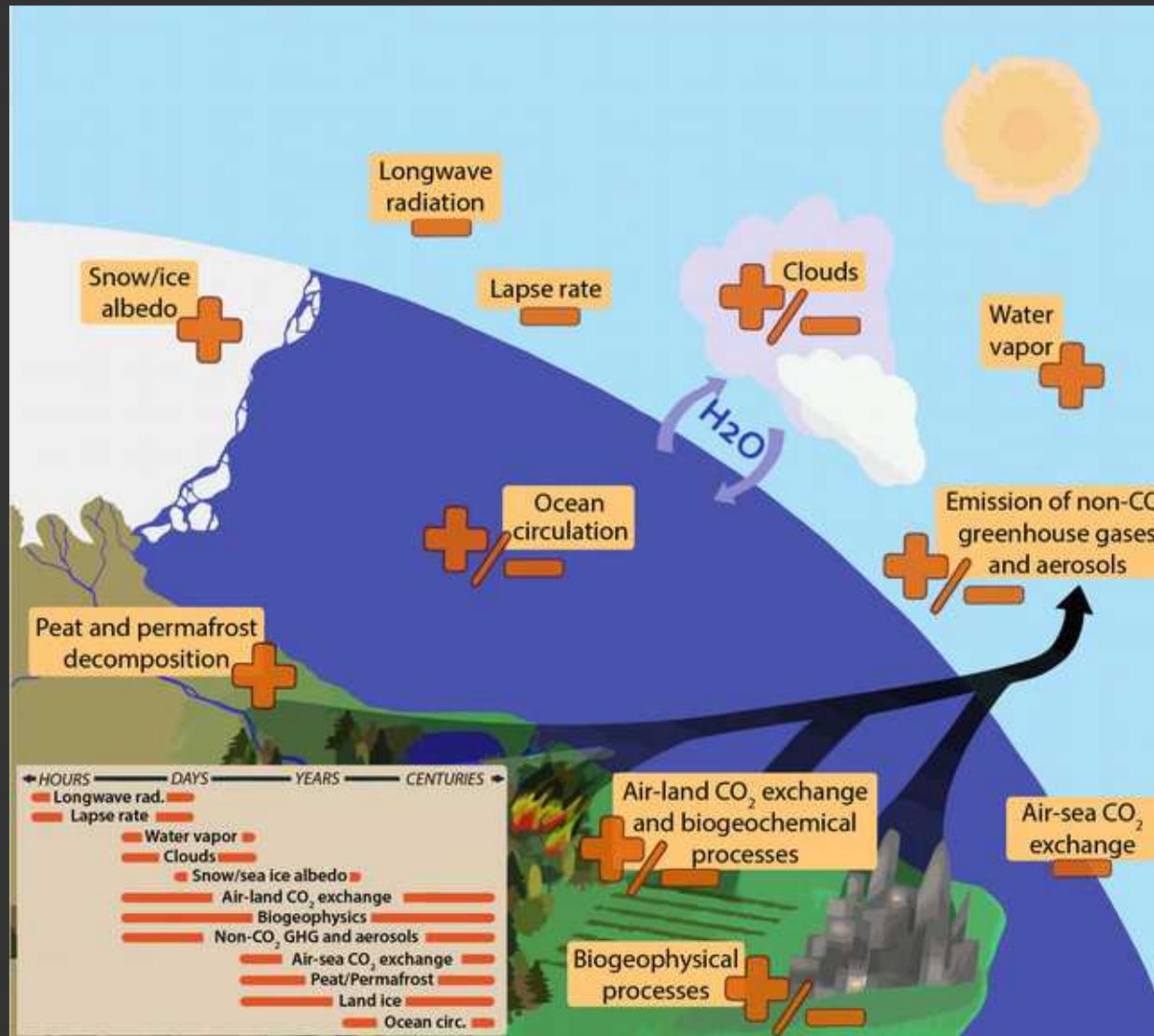
Flow of energy and elements between populations and communities and environment at biosphere scale (whole freaking Earth)



IPCC AR5 Fig 1\_2

# Global Ecology

Flow of energy and elements between populations and communities and environment at biosphere scale (whole freaking Earth)



# Biogeochemistry



Geophysics + Biology + Chemistry =

The bad@\$\$ crazy sum of all awesomeness!

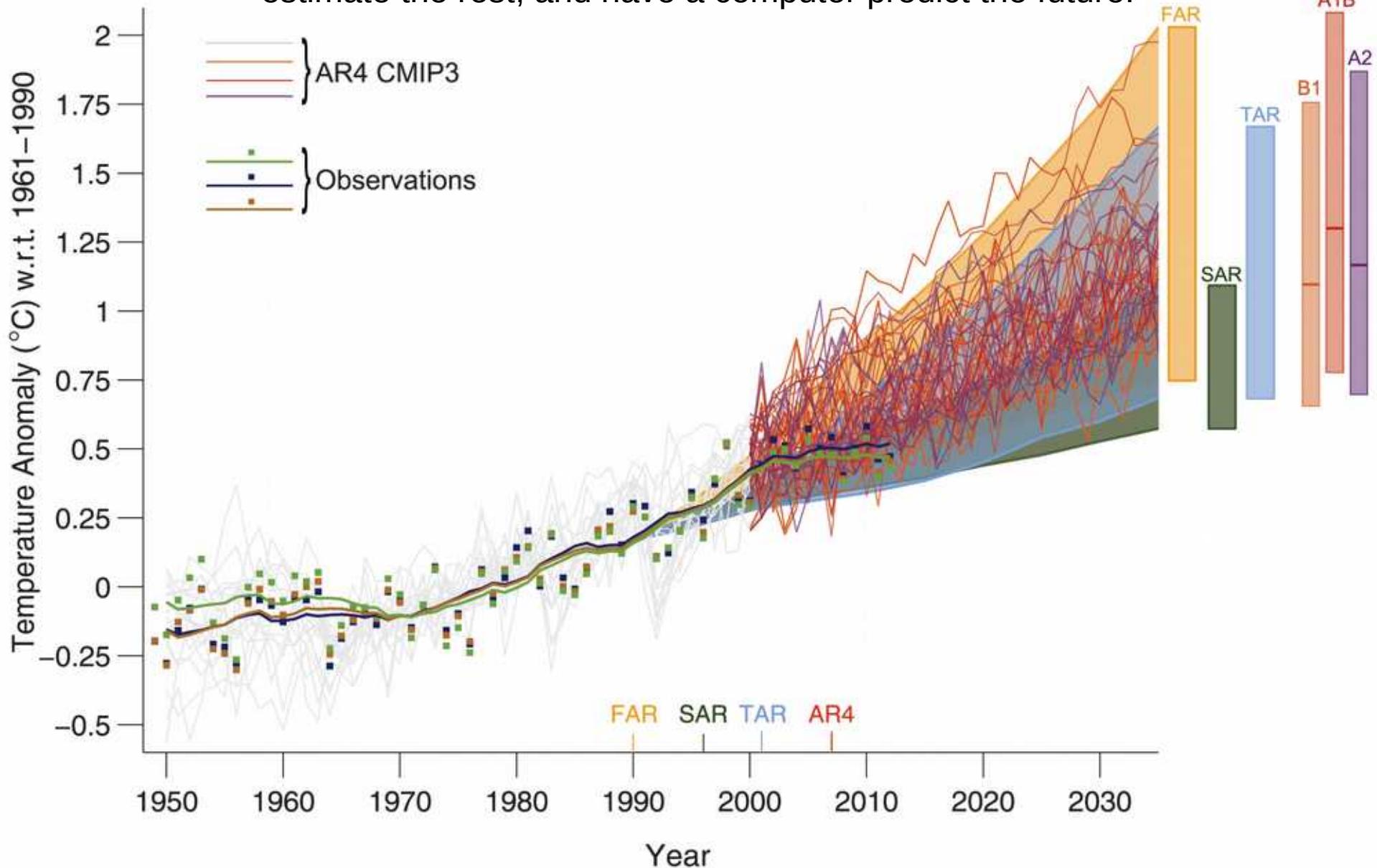
Climate patterns  
Agricultural efficiency  
Toxic mercury buildup in seafood  
Oil spill remediation  
Why a forest can change after burning  
Fate of air pollution  
Invasive species effects  
Emergence of ancient diseases  
Ocean currents  
Wastewater treatment methods  
Keeling curve  
Fishery management  
Elk hunt limits  
Evolution of Taq polymerase  
Age of the Earth  
Lead toxicity in Flint, MI  
...and a few other things.



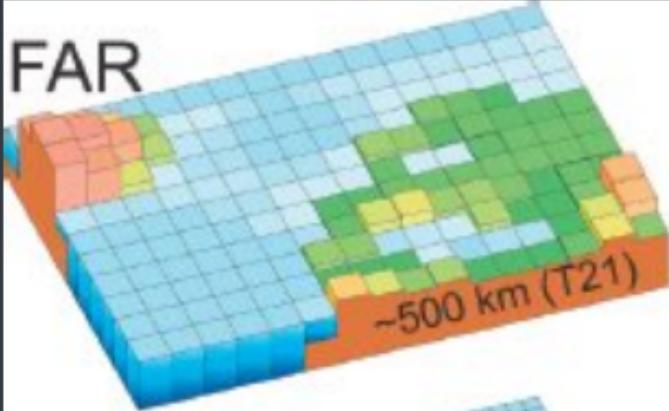
If you know everything about an environment (pH, sunlight, soil density, primary productivity, everything) ...

... then the genomes present in that environment could theoretically allow you to predict the future with perfect accuracy!

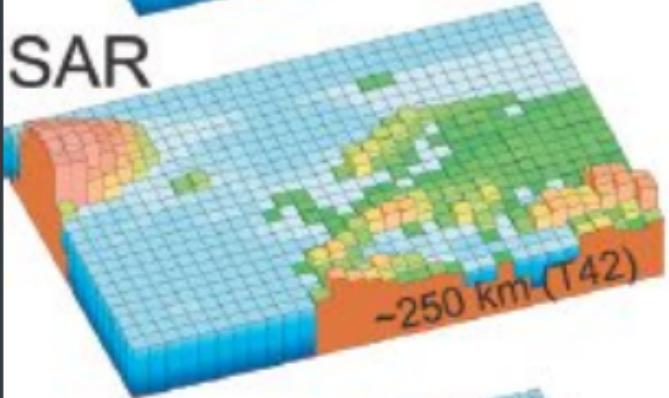
But this is too difficult, so we measure as much as possible, estimate the rest, and have a computer predict the future.



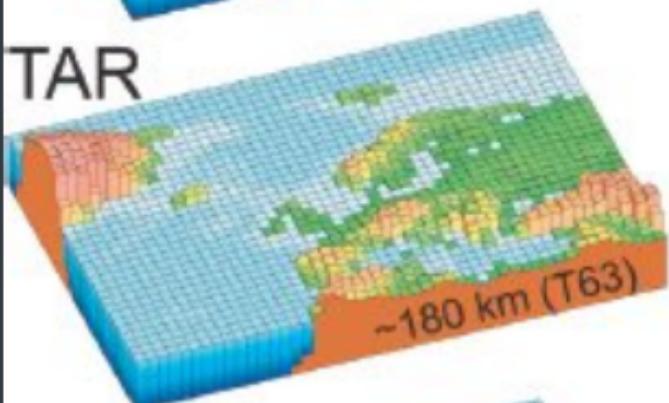
FAR



SAR



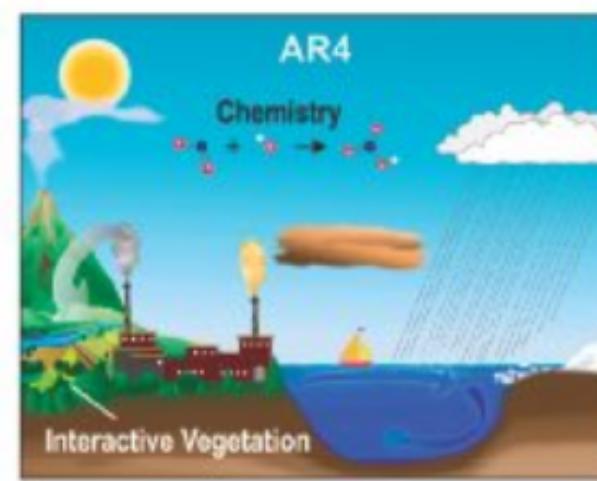
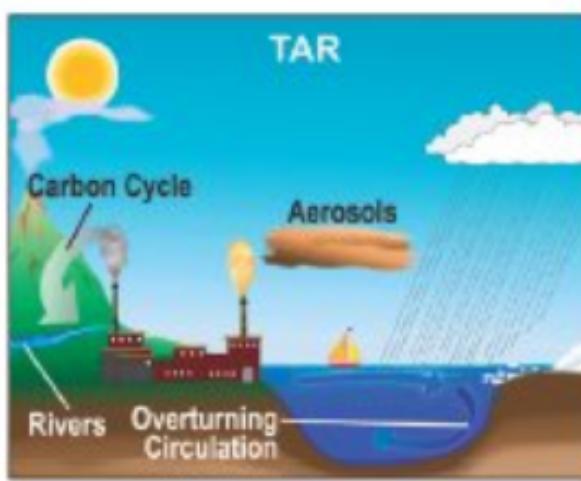
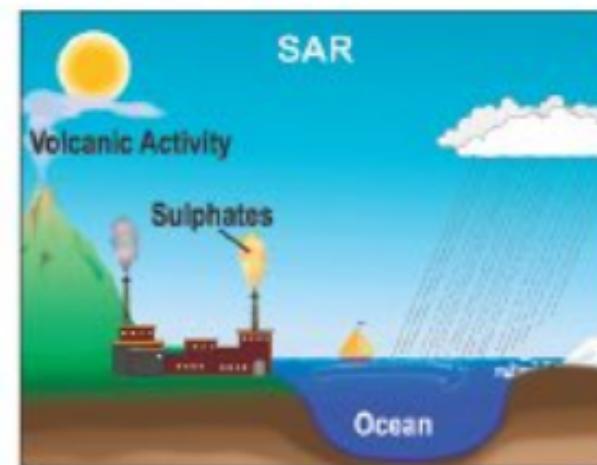
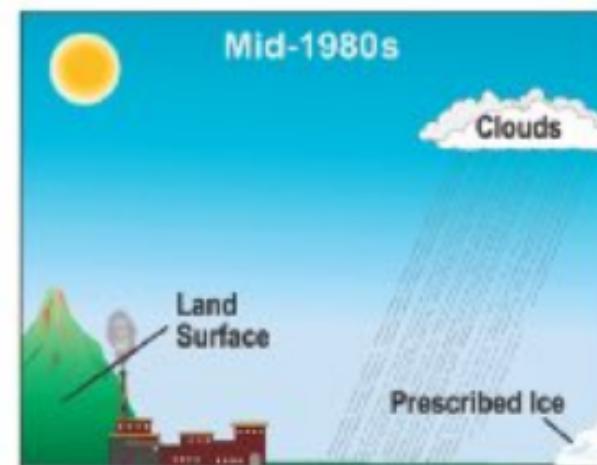
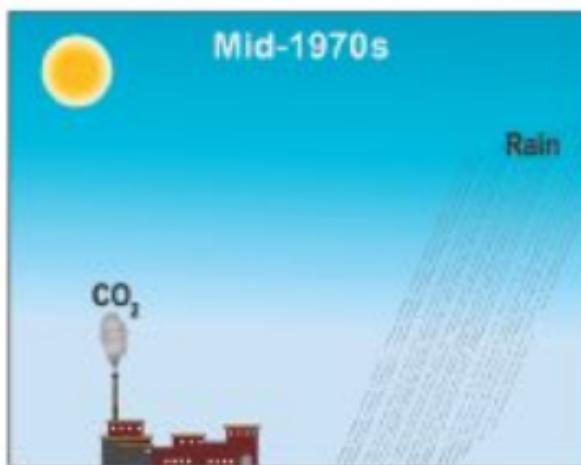
TAR



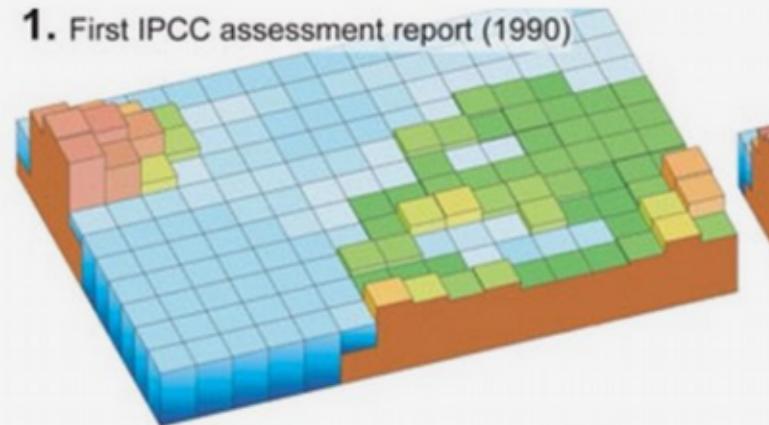
AR4



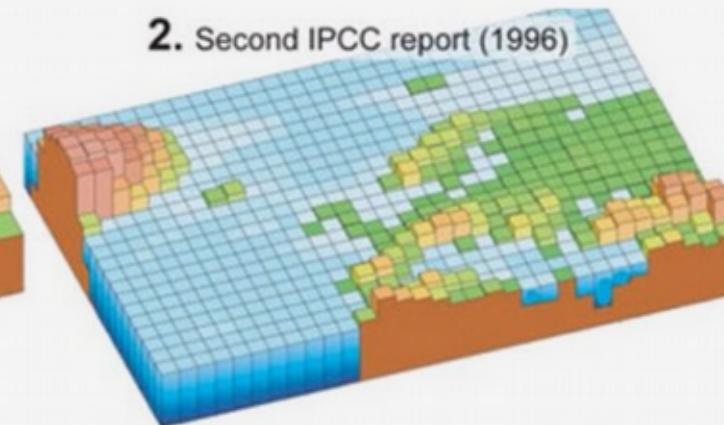
# The World in Global Climate Models



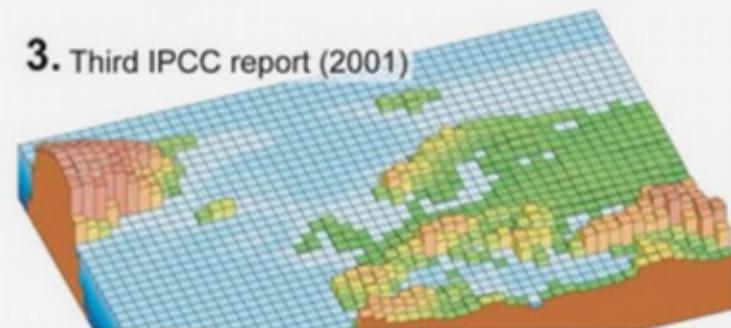
**1. First IPCC assessment report (1990)**



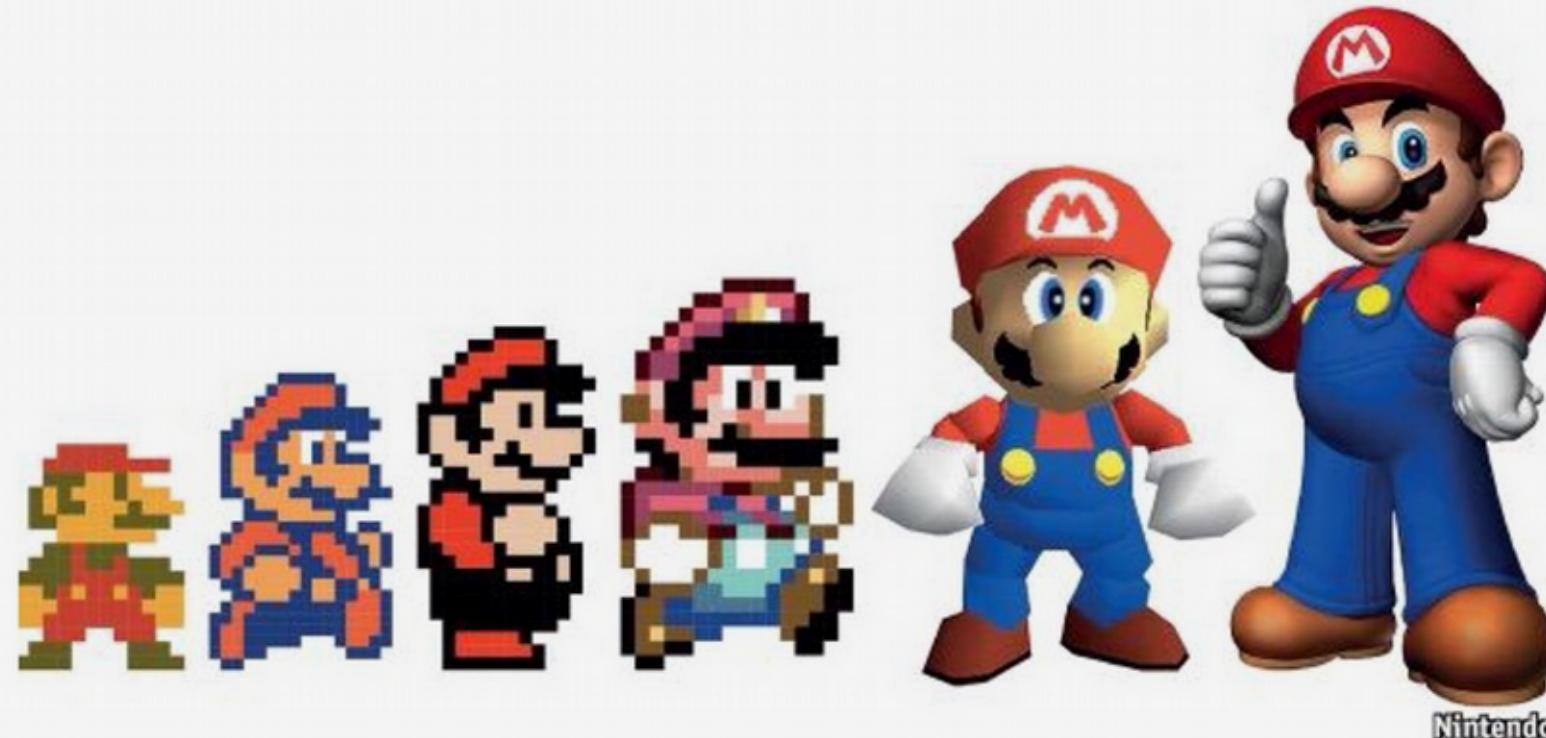
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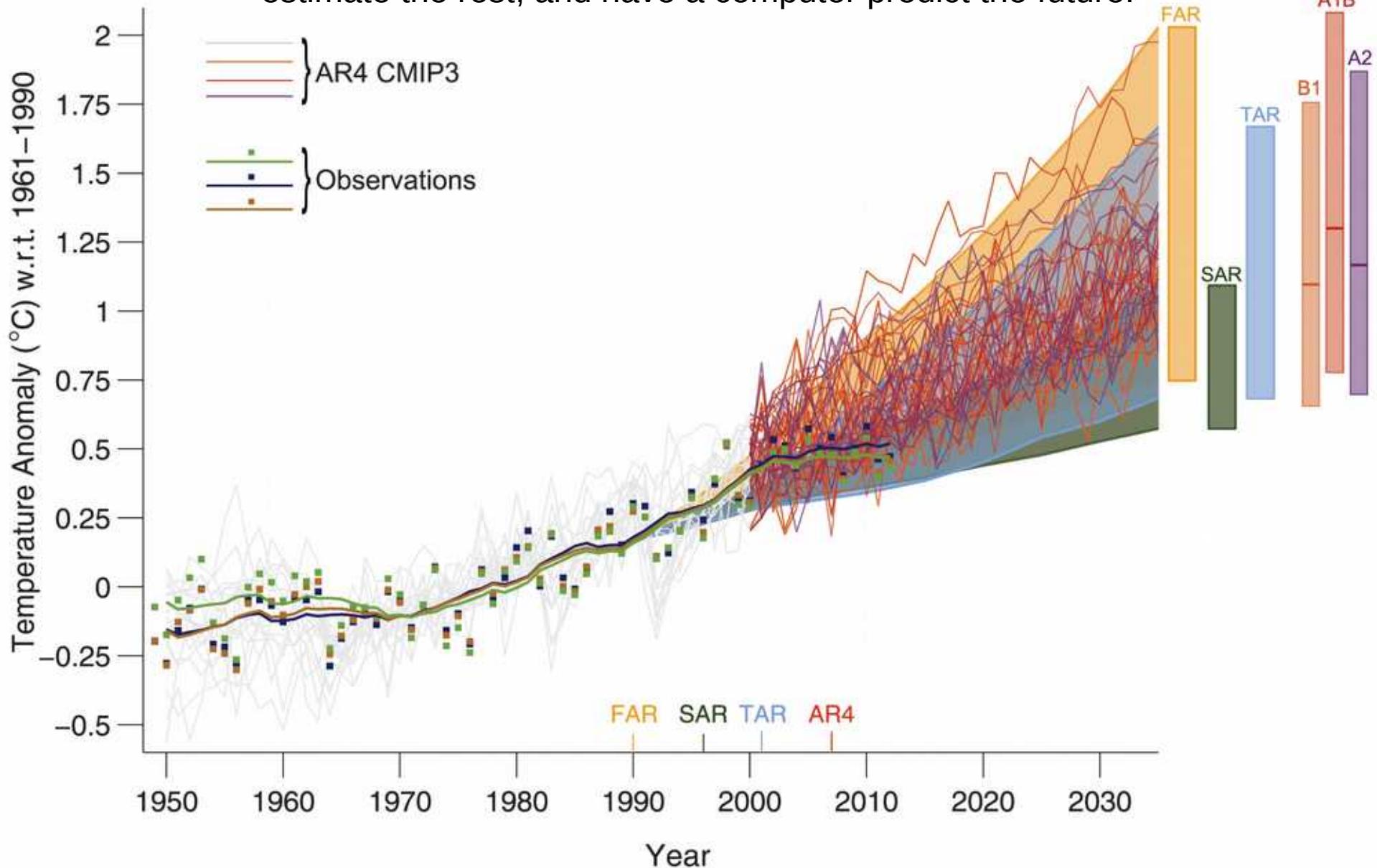


**4. Fourth IPCC report (2007)**



Nintendo

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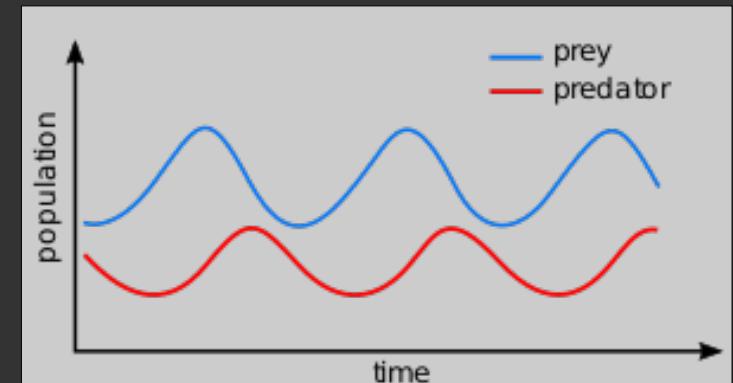


# Ecological modeling

Use known correlations between biotic and abiotic variables to predict population, community, or ecosystem level responses to projected changes of factors

Simple predator-prey equation

$$\begin{aligned}\frac{dX}{dt} &= \alpha \cdot X - \beta \cdot X \cdot Y \\ \frac{dY}{dt} &= \gamma \cdot \beta \cdot X \cdot Y - \delta \cdot Y\end{aligned}$$



- $X$  is the number/concentration of the prey species;
- $Y$  is the number/concentration of the predator species;
- $\alpha$  is the prey species' growth rate;
- $\beta$  is the predation rate of  $Y$  upon  $X$ ;
- $\gamma$  is the assimilation efficiency of  $Y$ ;
- $\delta$  is the mortality rate of the predator species

Add a single competitor:

$$\begin{aligned}\frac{dx_1}{dt} &= r_1 x_1 \left(1 - \left(\frac{x_1 + \alpha_{12} x_2}{K_1}\right)\right) \\ \frac{dx_2}{dt} &= r_2 x_2 \left(1 - \left(\frac{x_2 + \alpha_{21} x_1}{K_2}\right)\right).\end{aligned}$$

Add N more competitors:

$$\frac{dx_i}{dt} = r_i x_i \left(1 - \frac{\sum_{j=1}^N \alpha_{ij} x_j}{K_i}\right)$$

Add a single parasite species:

$$\begin{aligned}H_{t+1} &= k H_t e^{-a P_t} \\ P_{t+1} &= c H_t (1 - e^{-a P_t})\end{aligned}$$

# Ecological modeling

<https://trout.shinyapps.io/lahontan/>

Population of Lahontan trout based on water temp, riparian cover, given introductions.

$$\log f_G(g|\Theta, A) = \sum_{i=1}^{n+s-2} I_c(i) \log \frac{k_i(k_i-1)}{2\theta_{h(i)}} - \frac{k_i(k_i-1)\Delta u_i}{2\theta_{h(i)}},$$

$$h(i) := \begin{cases} 1, & \text{if } \sum_{j=1}^i I_c(j) \leq a_1, \\ j, & \text{if } \sum_{k=1}^{j-1} a_k < \sum_{j=1}^i I_c(j) \leq \sum_{k=1}^j a_k \end{cases}.$$

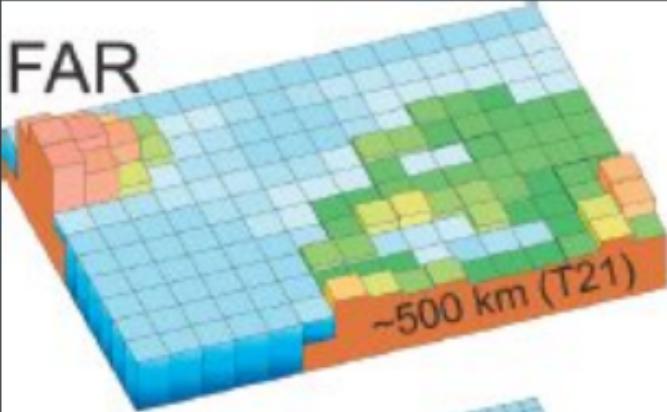
Projected uncertainty

$$f_\Theta(\Theta) \propto \frac{1}{\theta_1} \prod_{j=2}^m \theta_{j-1} \exp(-\theta_j/\theta_{j-1}).$$

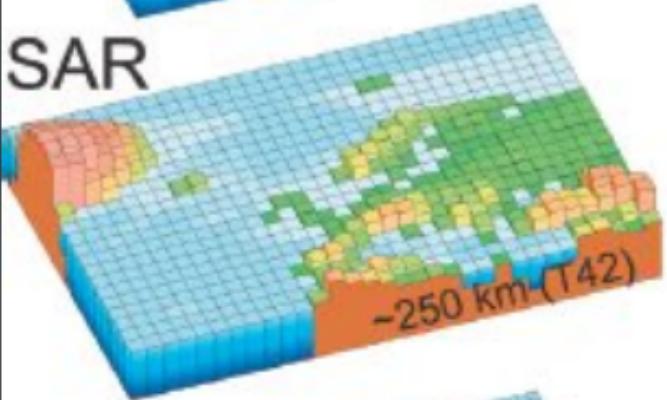
Distribution of uncertainty

$$f_{iso}(\Theta, A, \Omega, g|D, \mu) = \frac{1}{Z} \Pr\{D|\mu, g\} f_G(g|\Theta, A) \times f_\Theta(\Theta) f_A(A) f_\Omega(\Omega).$$

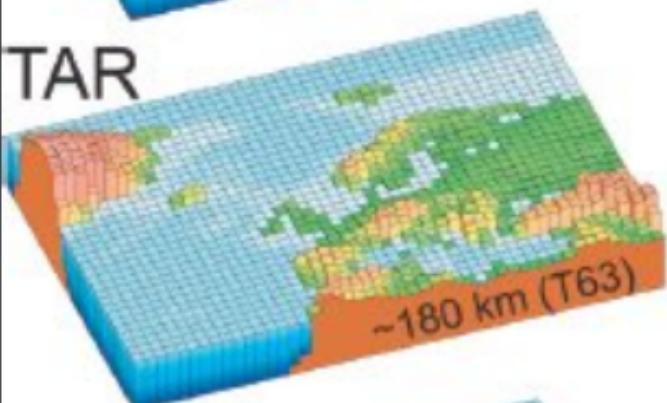
FAR



SAR



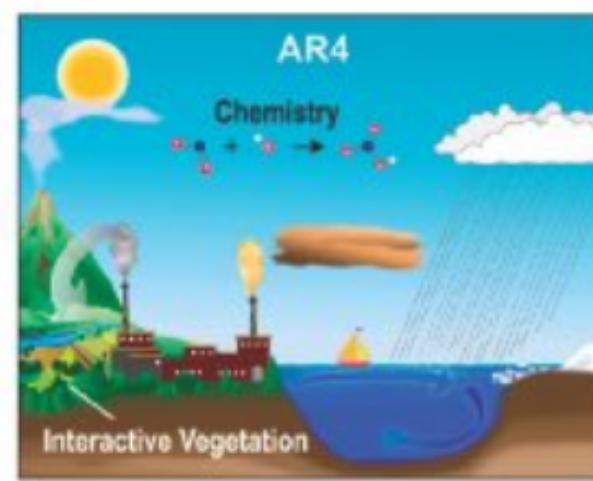
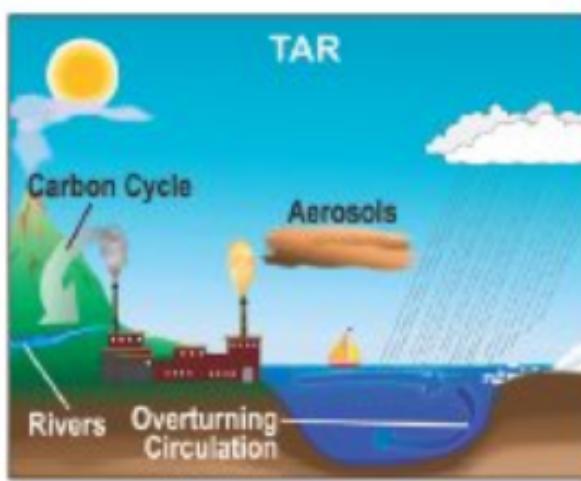
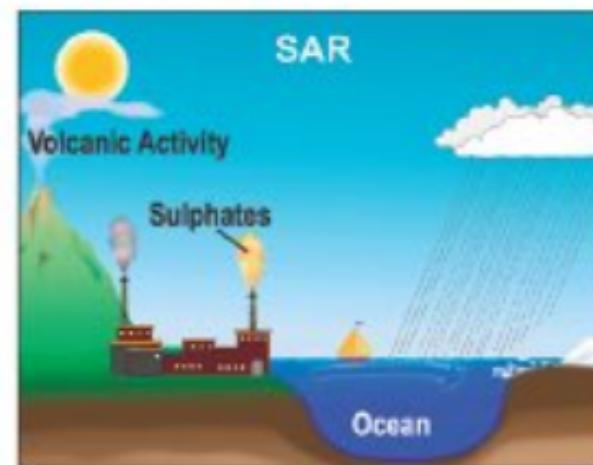
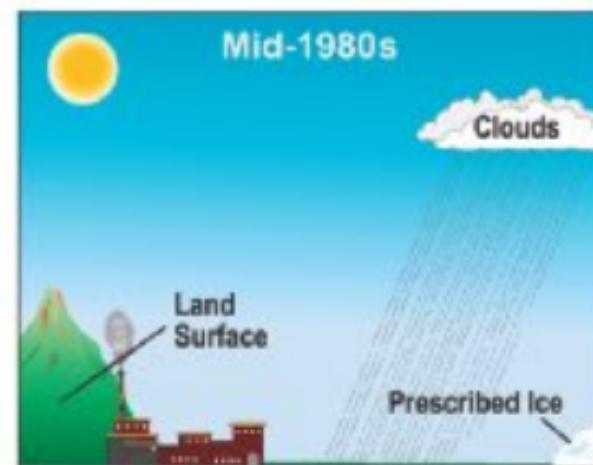
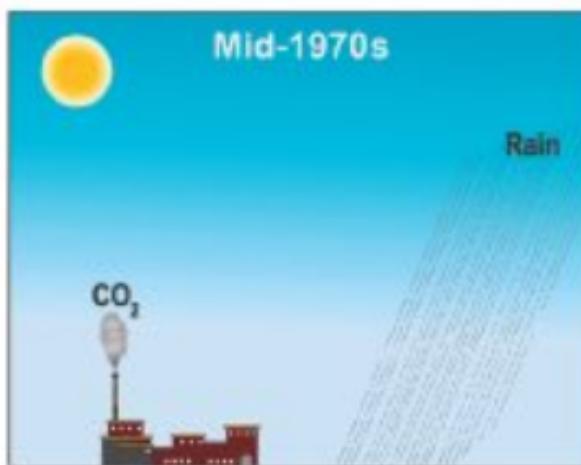
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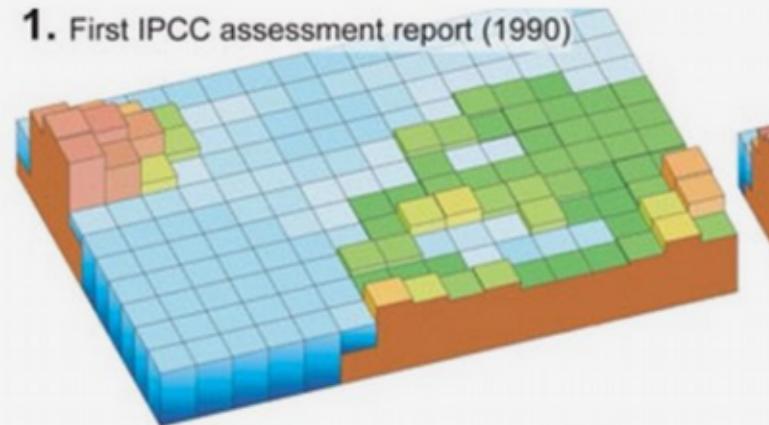
AR4



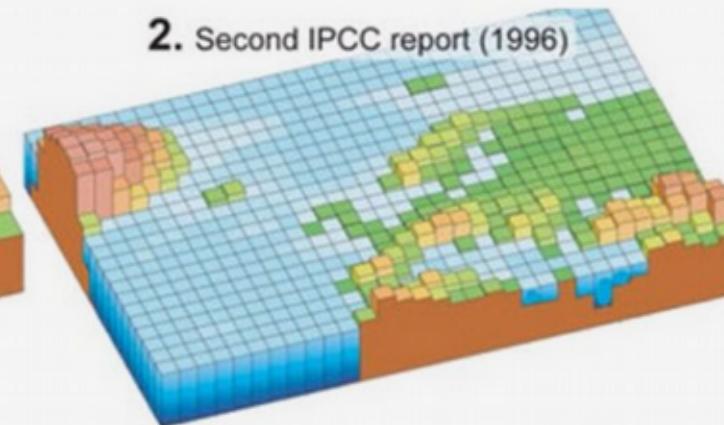
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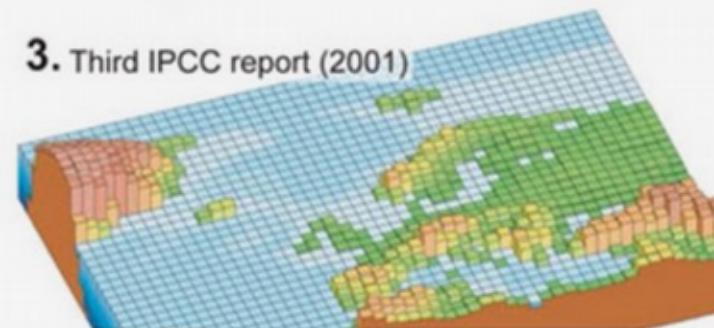
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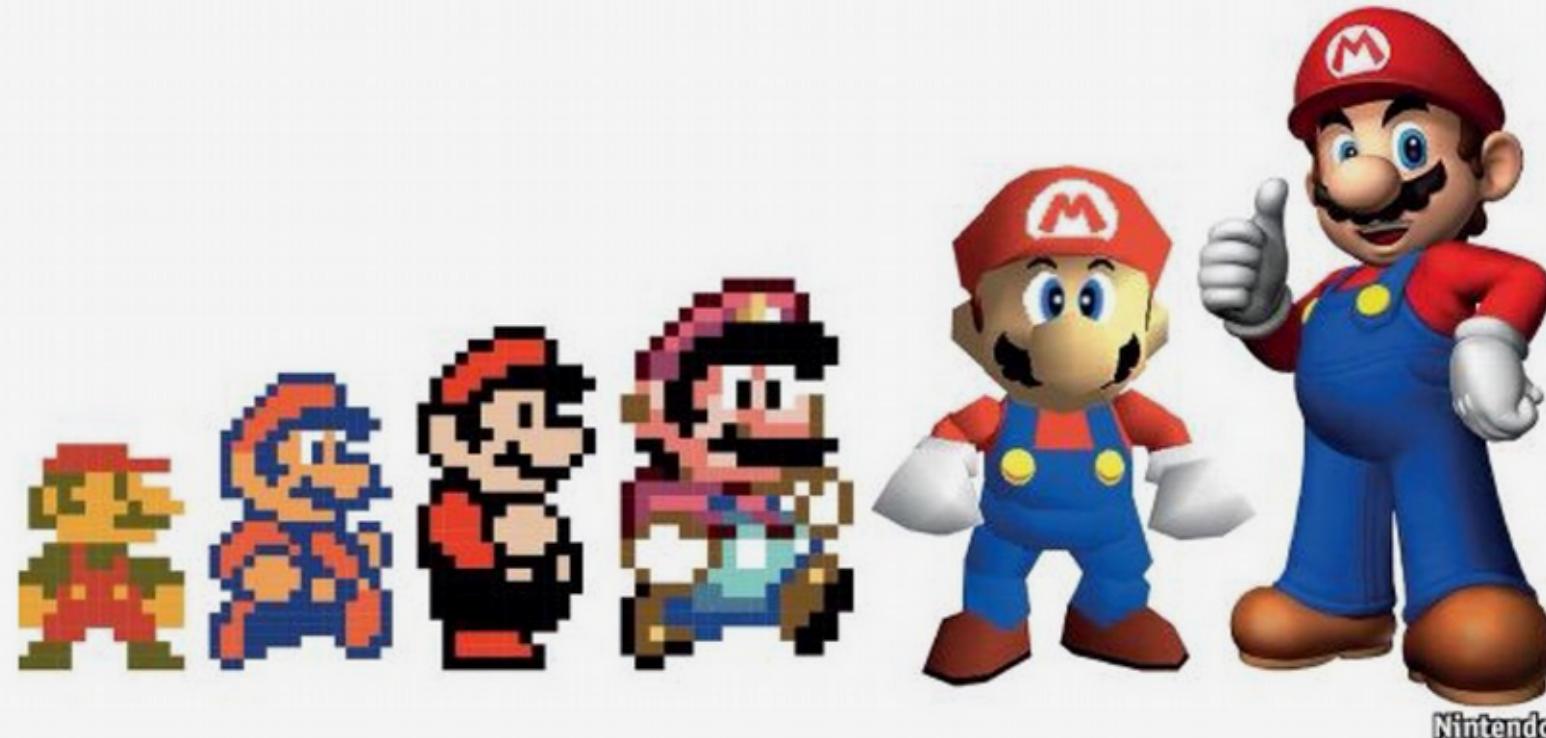
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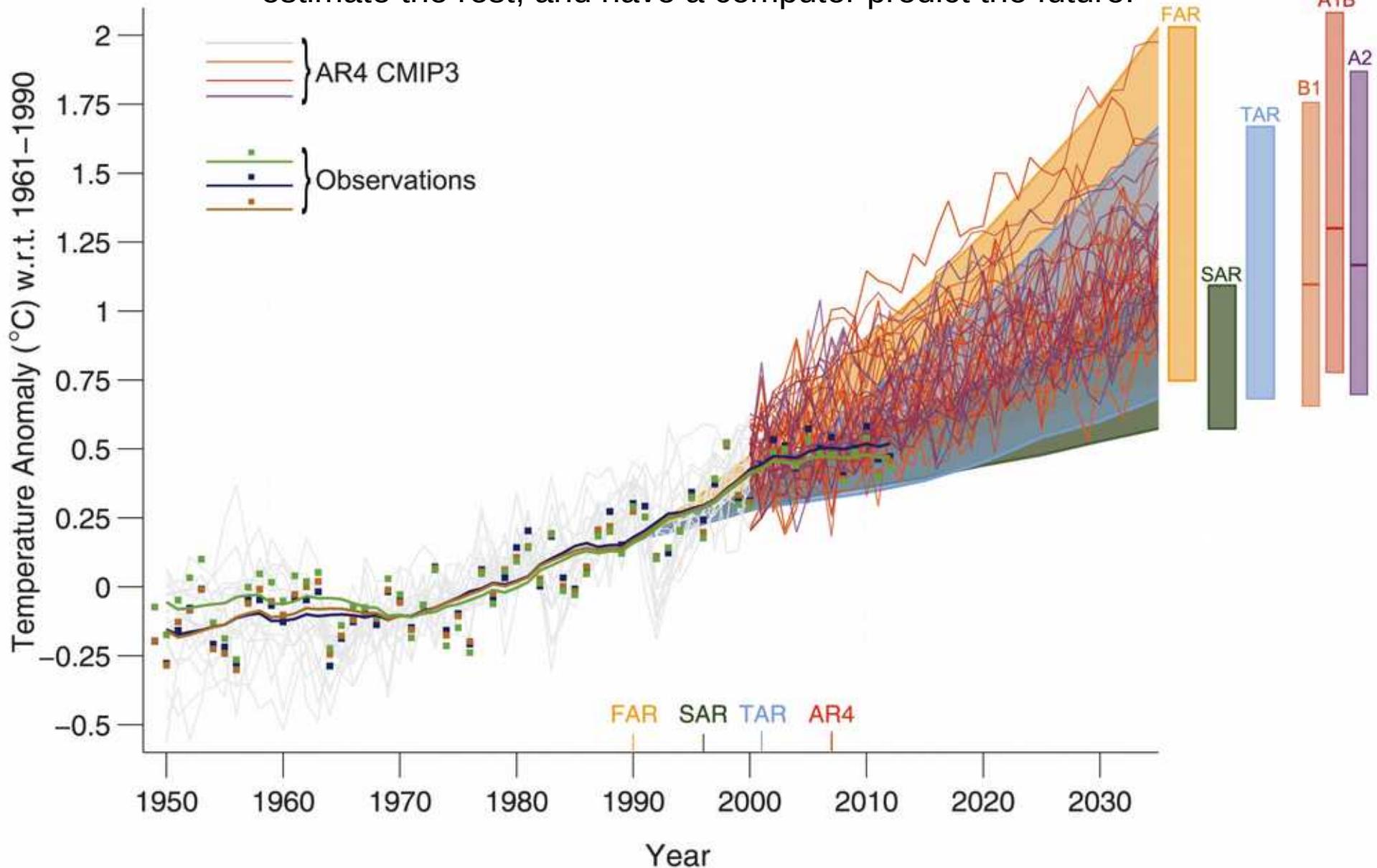


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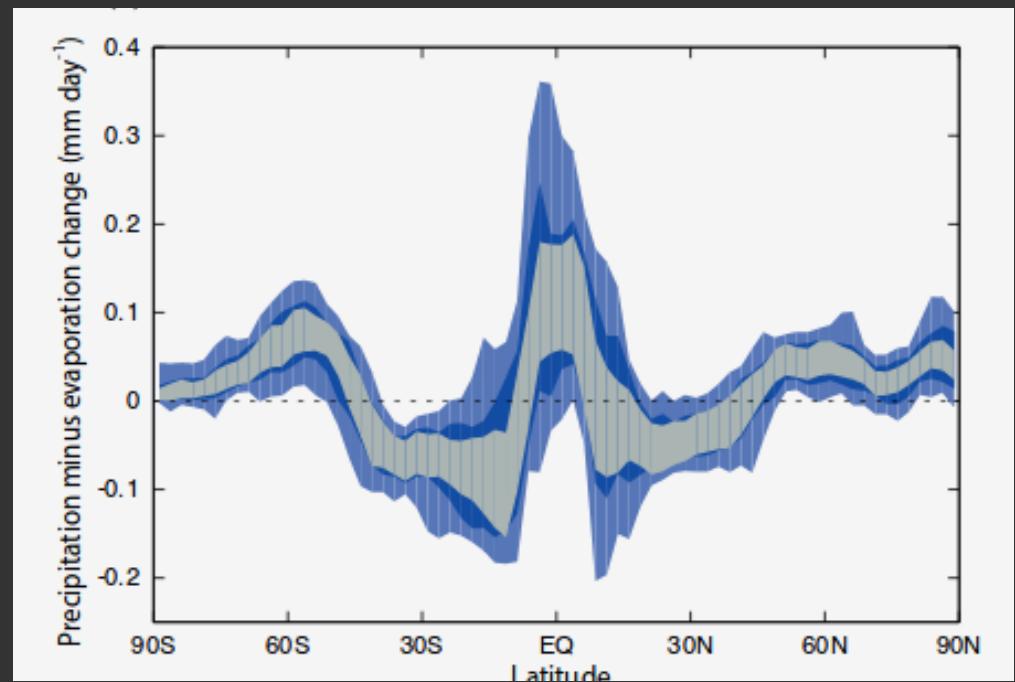
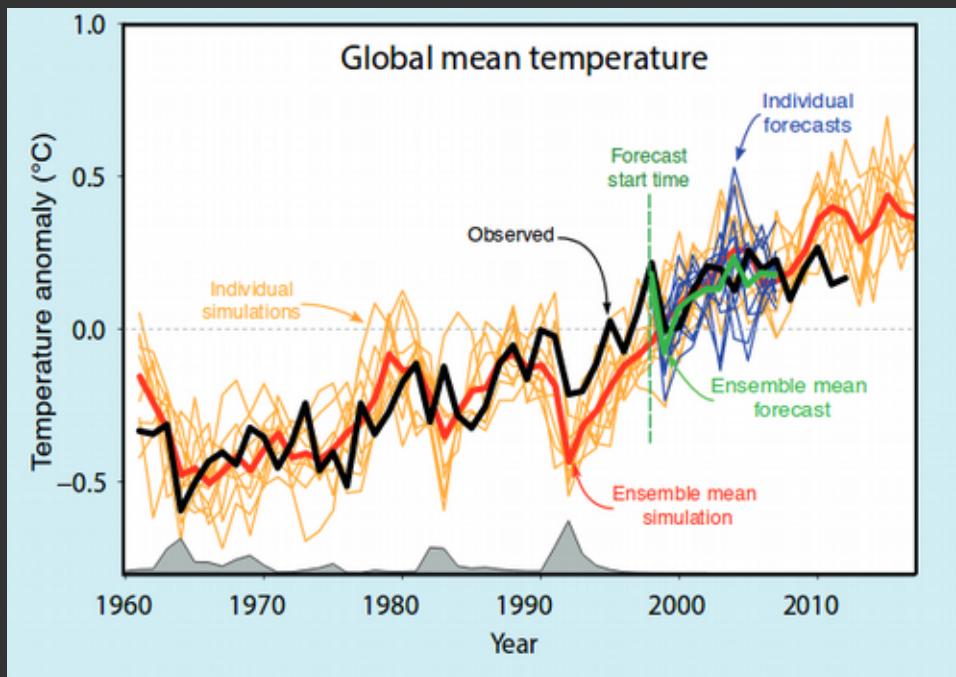
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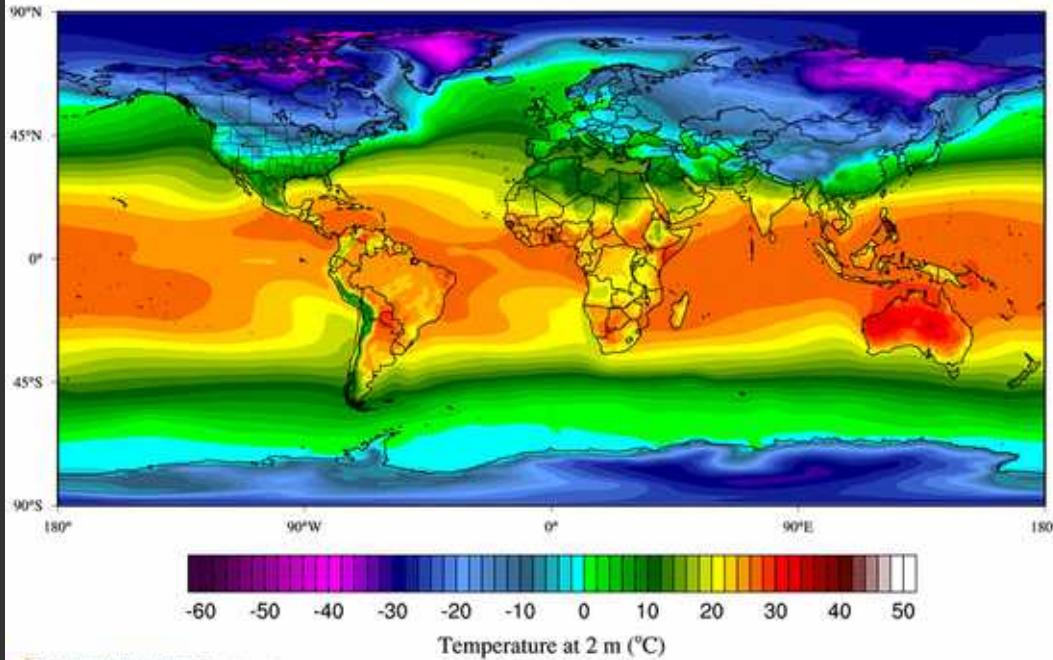


# Climate plays huge role in ecology

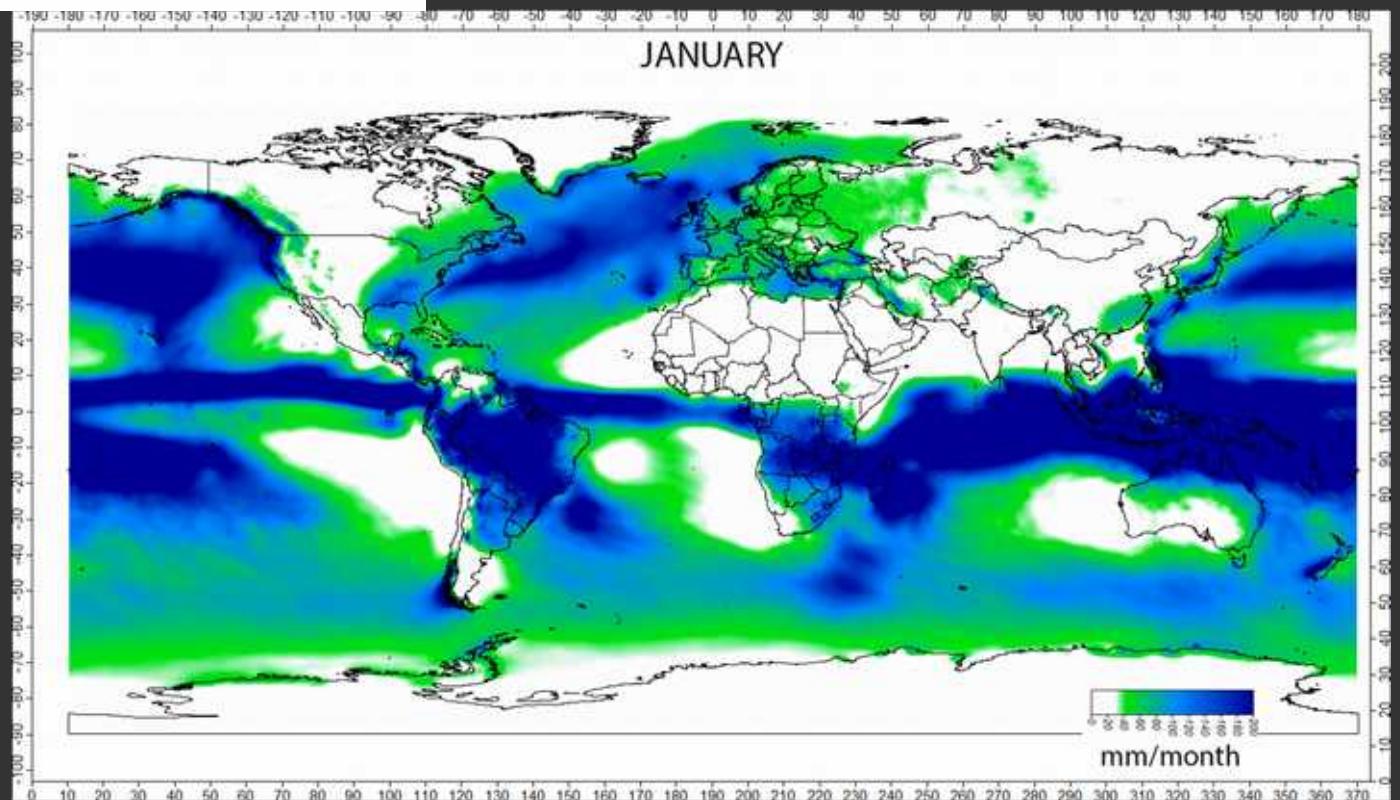
Climate is NOT weather!!!



Long-term trends in temperature and precipitation



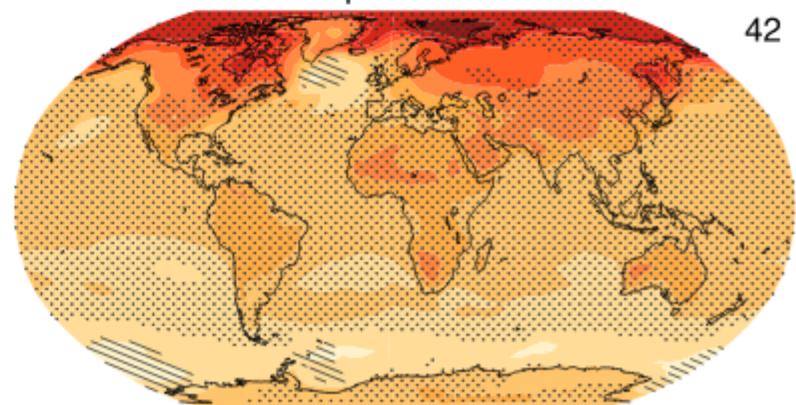
Temperature



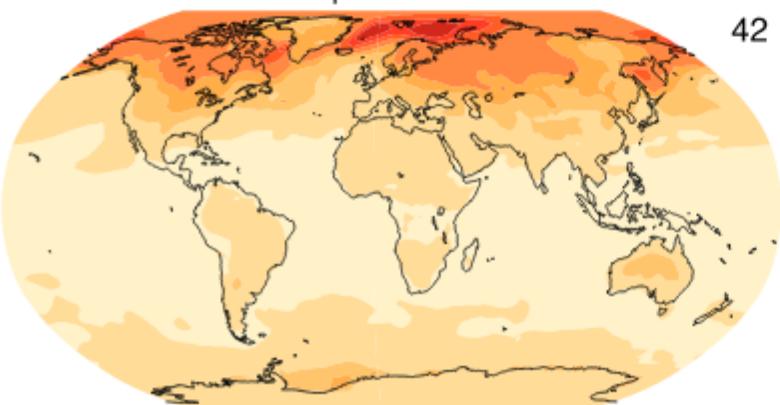
Precipitation

### Seasonal mean air temperature change (RCP4.5: 2016-2035)

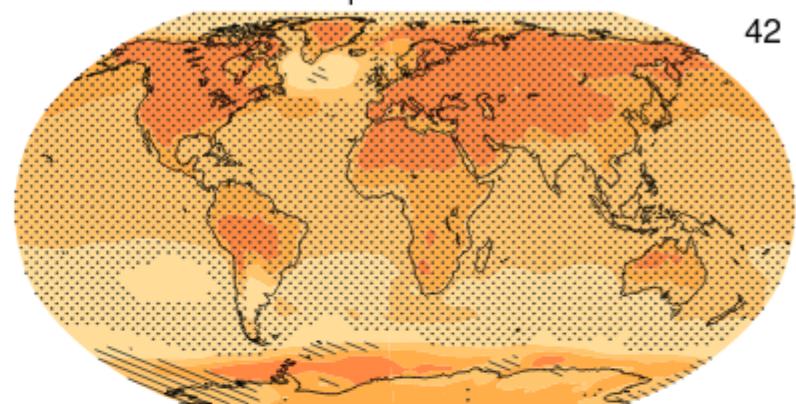
$\Delta$  Temperature - DJF



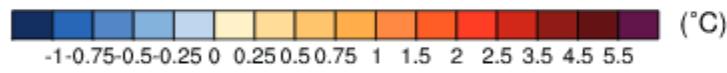
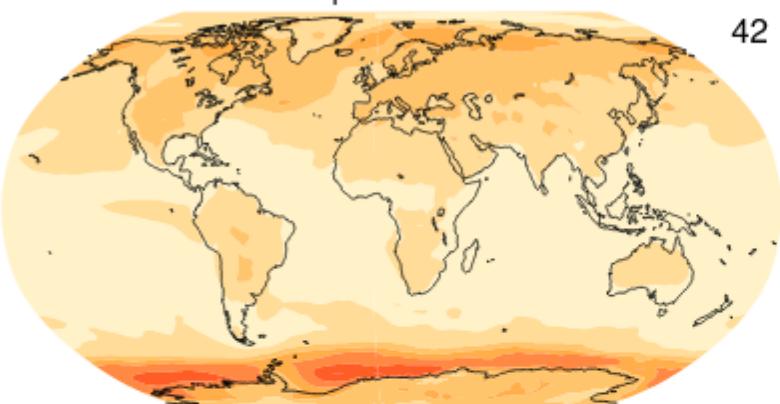
$\sigma$  Temperature - DJF



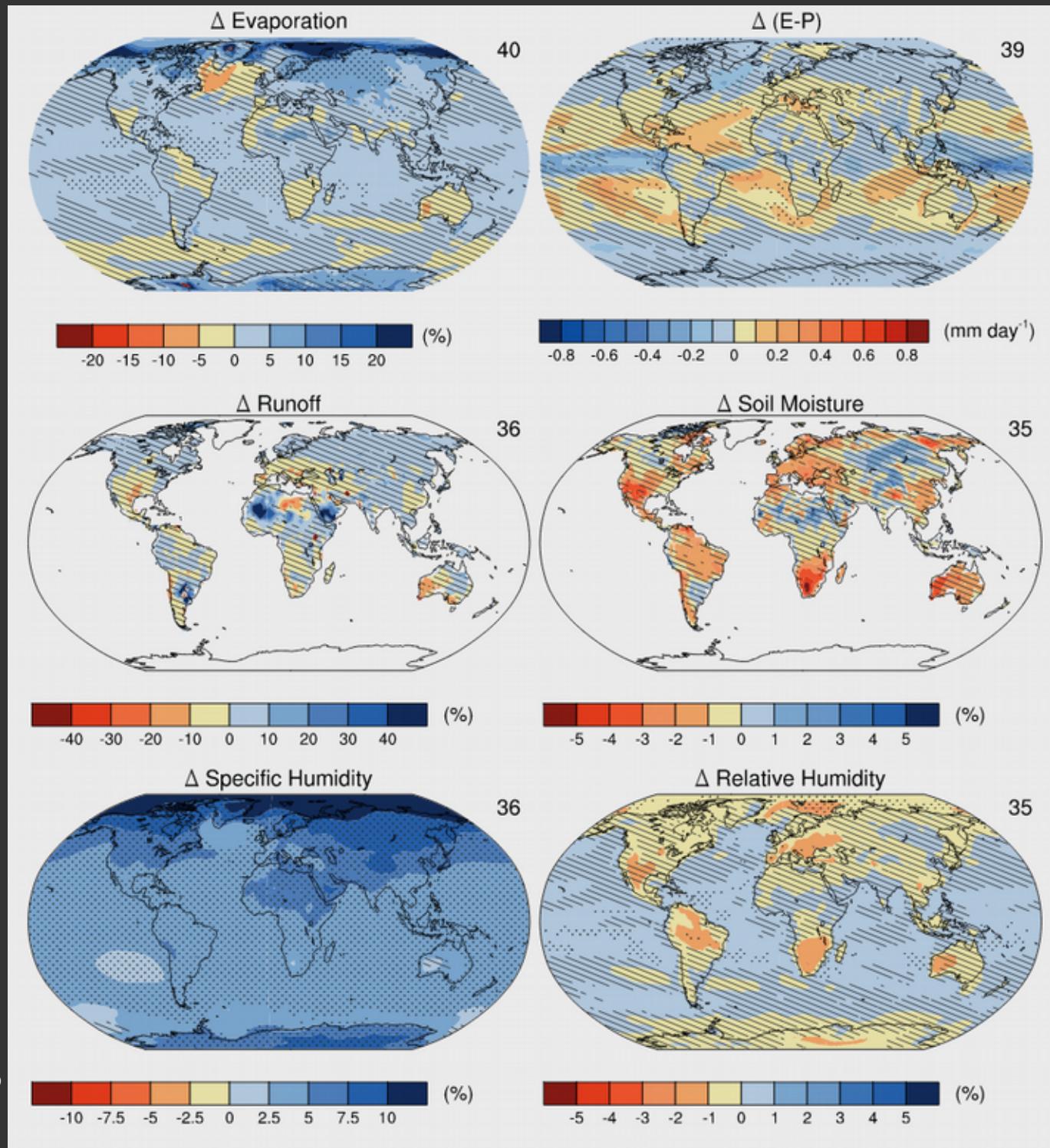
$\Delta$  Temperature - JJA



$\sigma$  Temperature - JJA

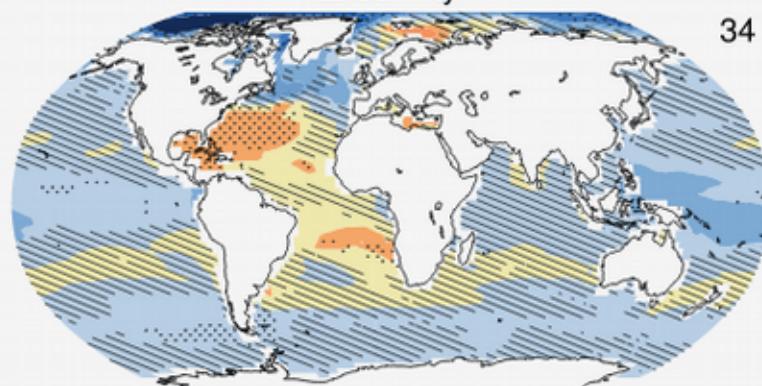


Predictions for 2035  
95% certainty

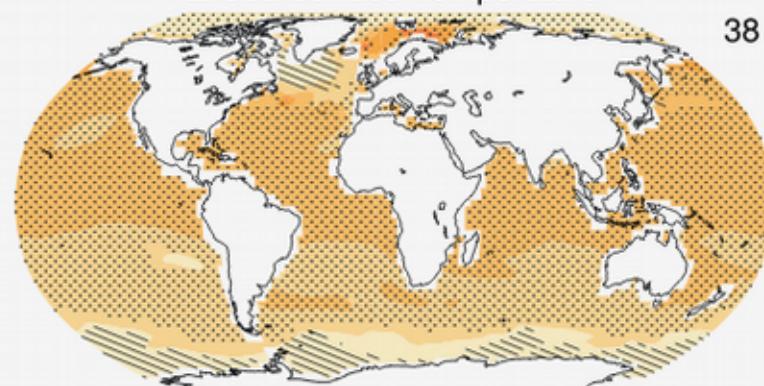


### Annual mean ocean surface change (RCP4.5: 2016-2035)

$\Delta$  Salinity



$\Delta$  Sea Surface Temperature



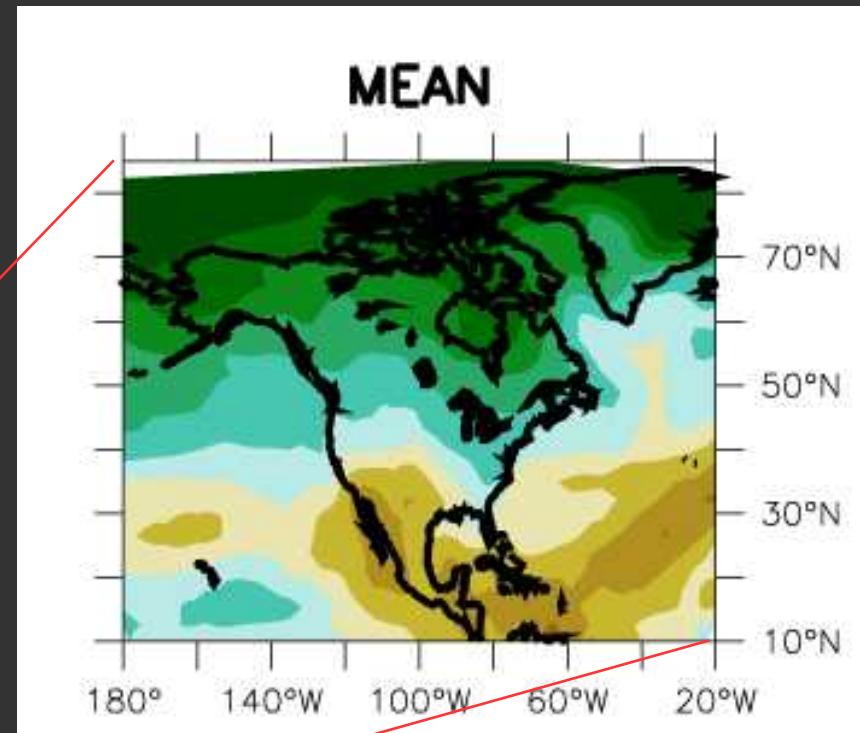
**Figure 11.20** | CMIP5 multi-model ensemble mean of projected changes in sea surface temperature (right panel; °C) and sea surface salinity (left panel; practical salinity units) for 2016–2035 relative to 1986–2005 under RCP4.5. The number of CMIP5 models used is indicated in the upper right corner. Hatching and stippling as in Figure 11.10.

### Annual Mean Precip Response (%)



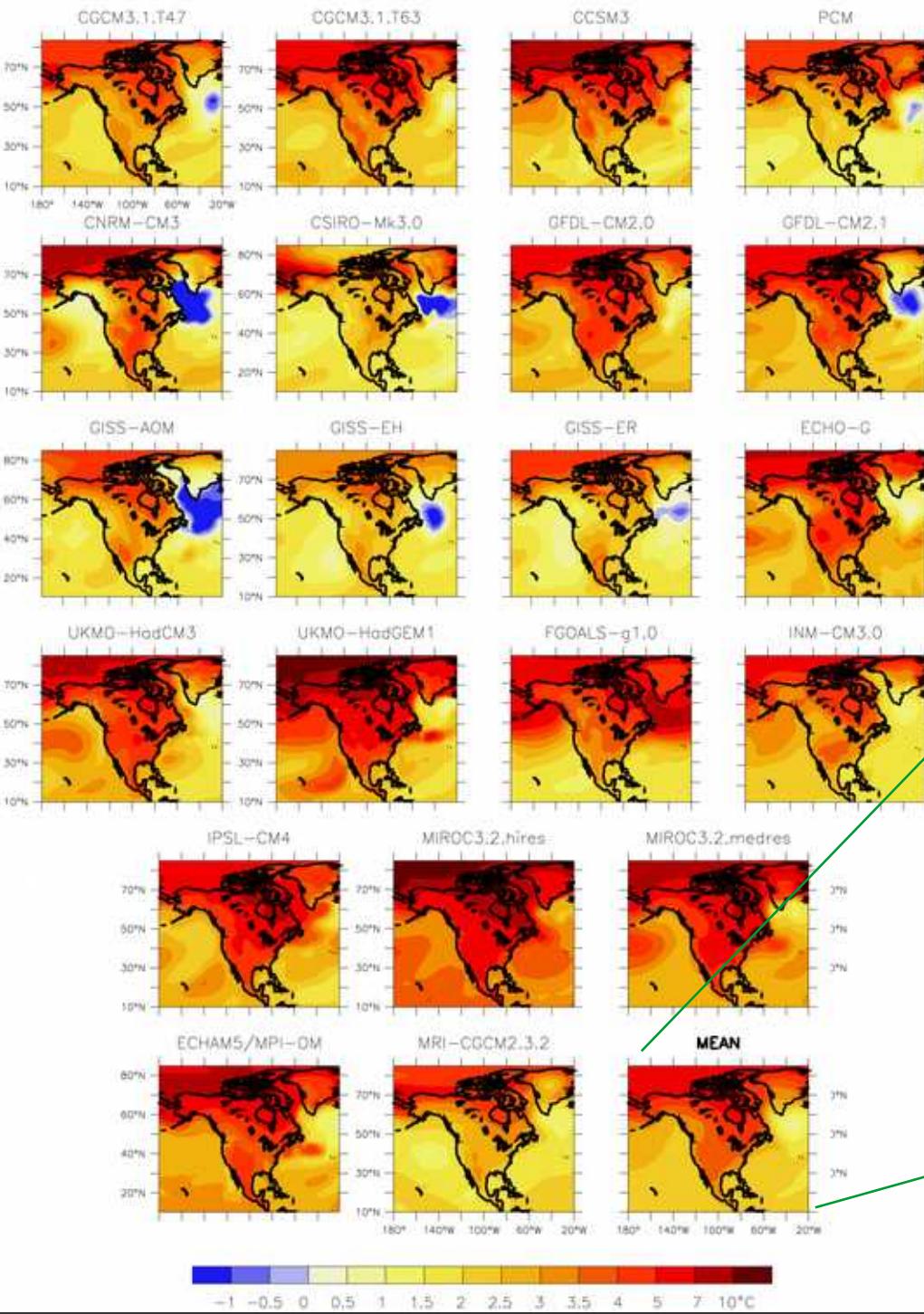
20 independent research groups around the world came up with their own models from the data.

The IPCC figure on the left compiles their separate predictions for 2035.

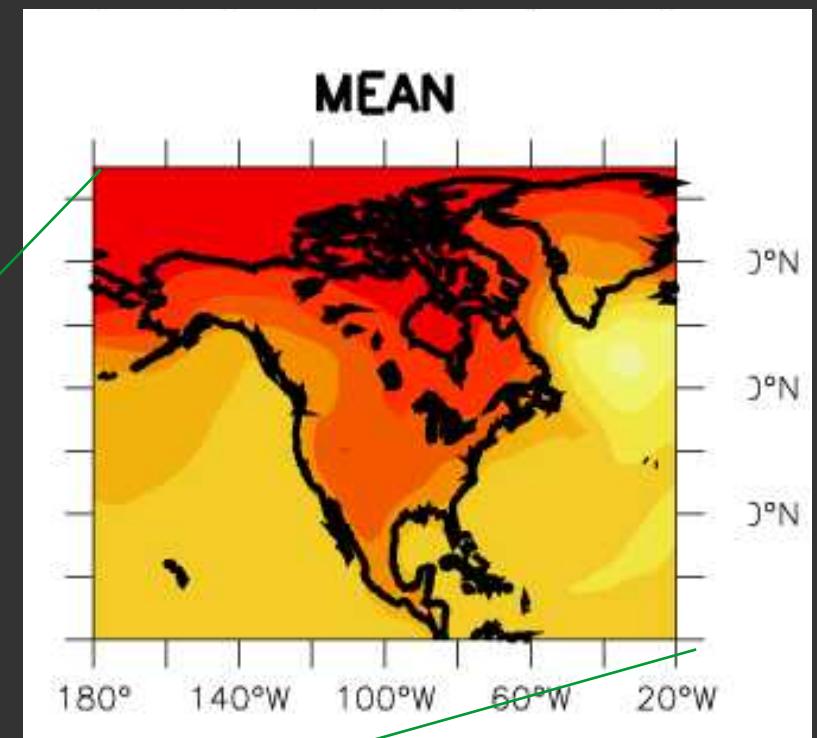


The average of all the model predictions

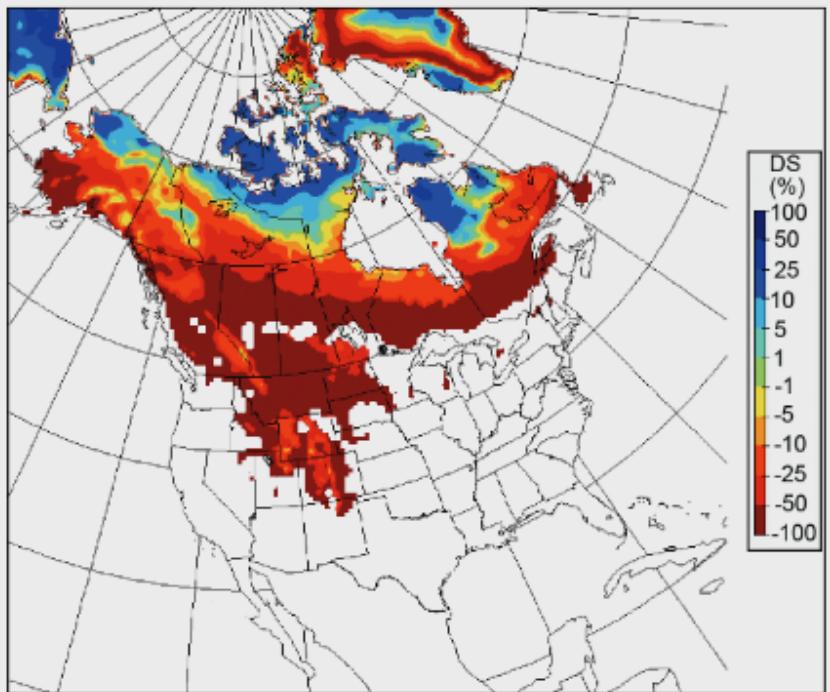
### Annual Mean Surface Air Temp Response ( $^{\circ}\text{C}$ )



Same thing, but temperature



# Snowpack (albedo)



**Figure 11.13.** Percent snow depth changes in March (only calculated where climatological snow amounts exceed 5 mm of water equivalent), as projected by the Canadian Regional Climate Model (CRCM; Plummer et al., 2006), driven by the Canadian General Circulation Model (CGCM), for 2041 to 2070 under SRES A2 compared to 1961 to 1990.

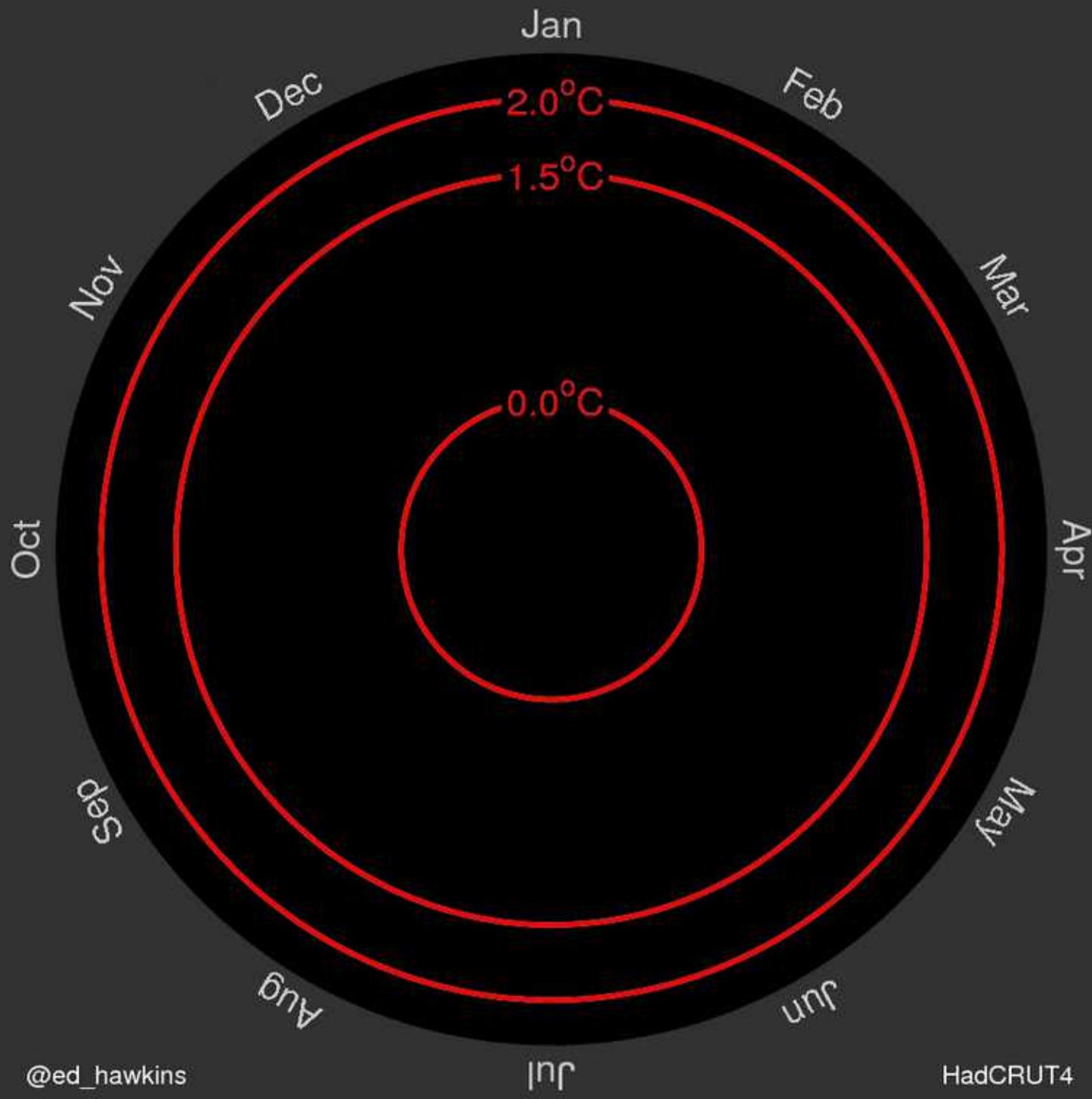
Given current trends in human activity (unchanged), Utah snowpack is projected to be around 30% of what it currently averages

These models have 80% accuracy

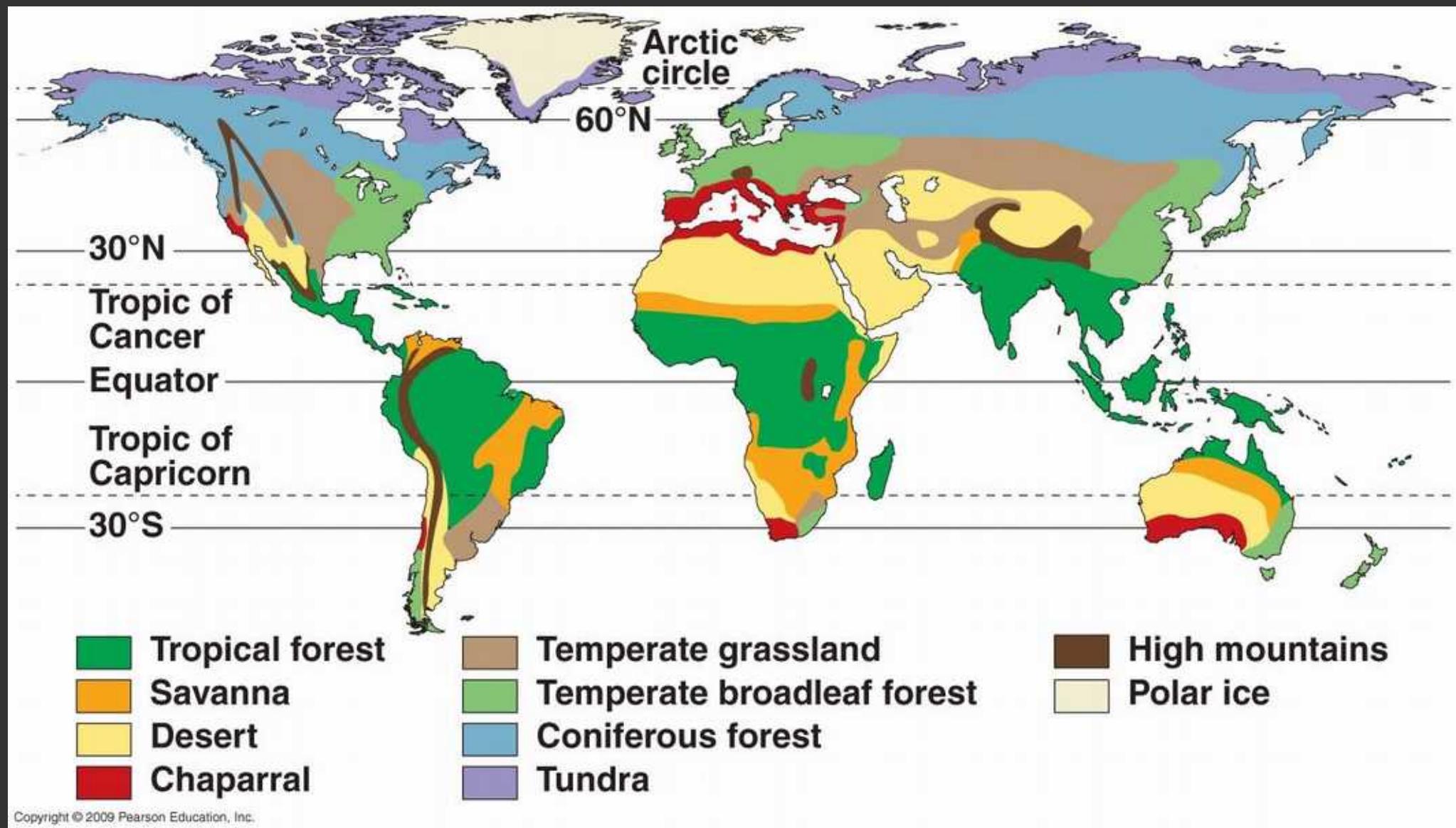
So, conservatively, we can say that if something doesn't change, Wasatch/Unita will have half their current snow within ~50 years

Orem = St. George?

# Global temperature change (1850–2016)



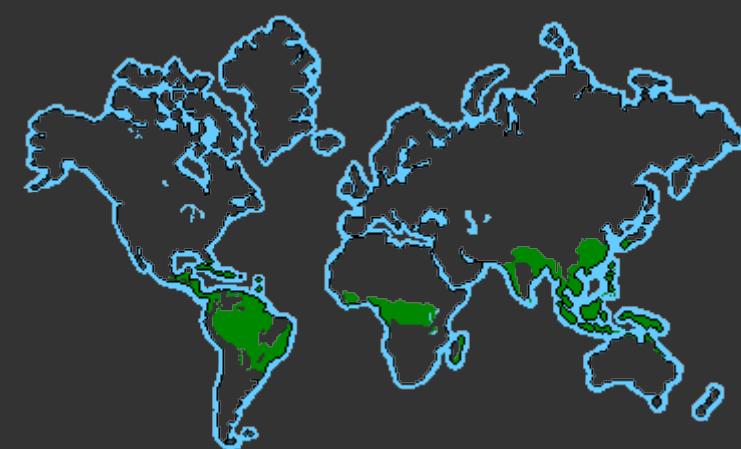
# Due to temperature and precipitation (mostly)



# Tropical Forest



Warm and wet



# Savanna (tropical grassland)



Warm and not wet enough for forest



# Desert



Hot/Cold and Dry



# Chaparral



Coastal, hot and dry  
Lots of fires



# Temperate Grassland



Erratic precipitation (dry-ish)  
Less rain than savanna  
Lots of fires



# Taiga



# Deciduous Forest



Wet and seasonal



# Tundra



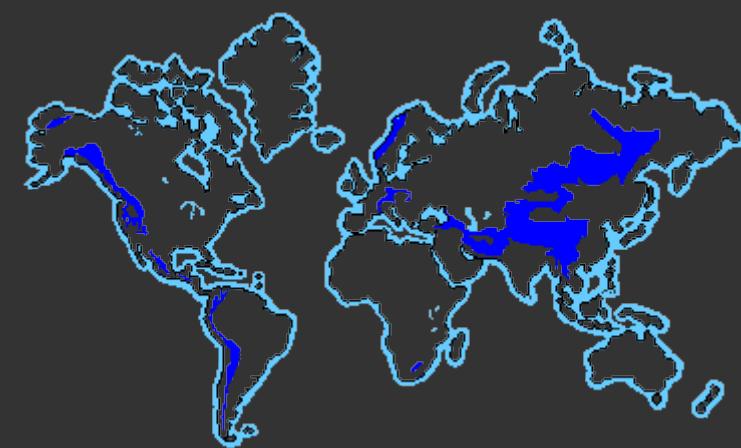
Dry and cold  
Low-nutrient  
No trees



# High Mountains (Apline)



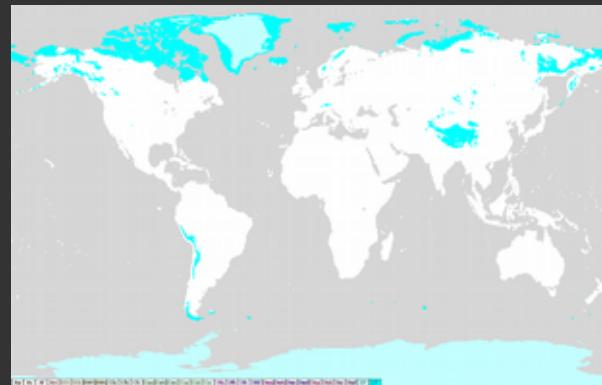
Cold  
High-elevation  
High-UV  
Low diversity



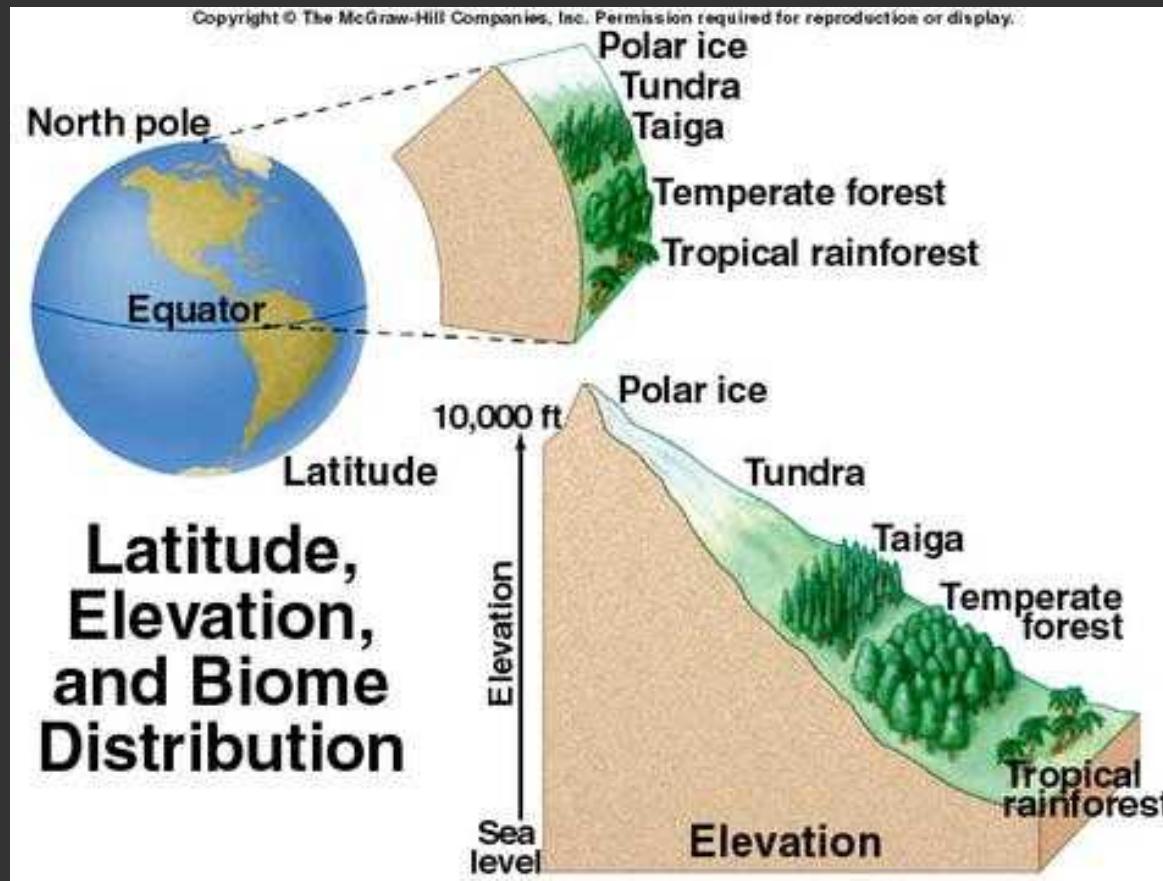
# Polar Ice



Frozen and very dry  
No plants



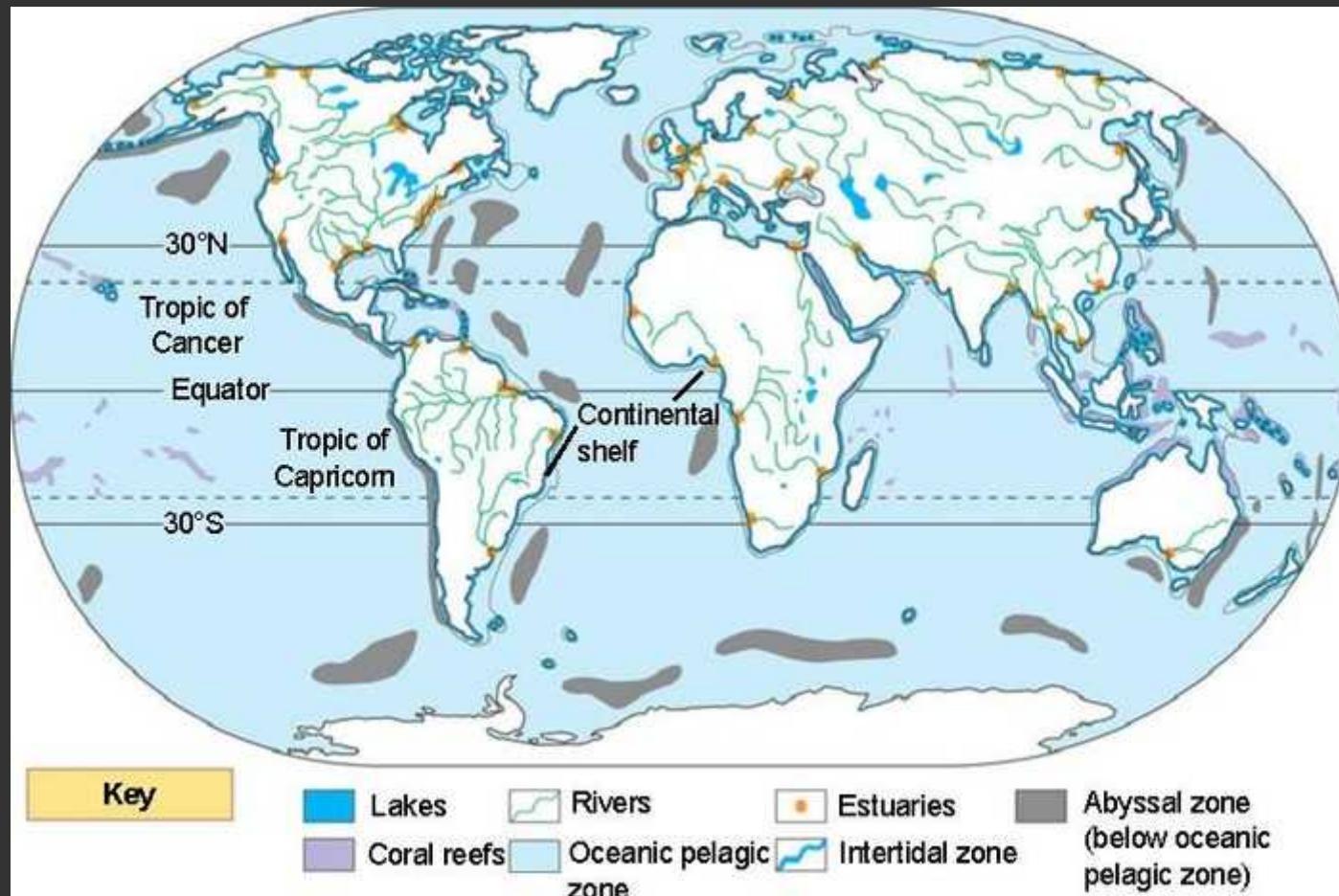
# Location, Location, Location



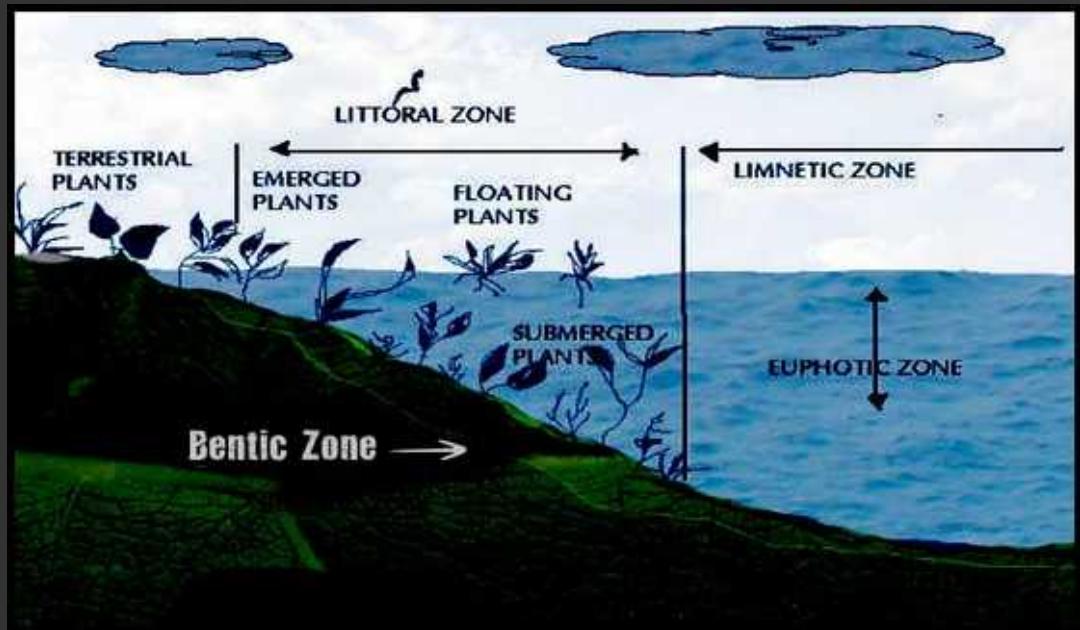
# How do you turn one biome into another?



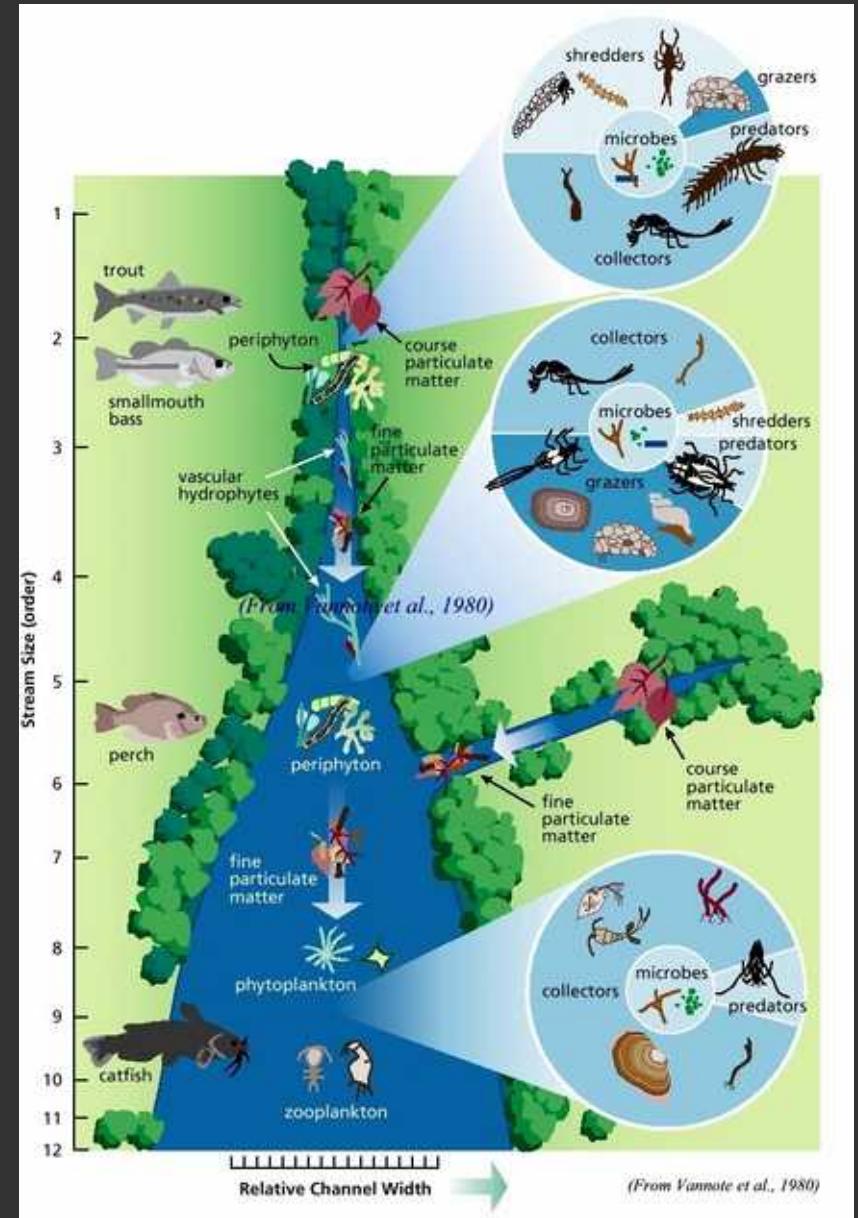
# Aquatic Biomes



# Lake



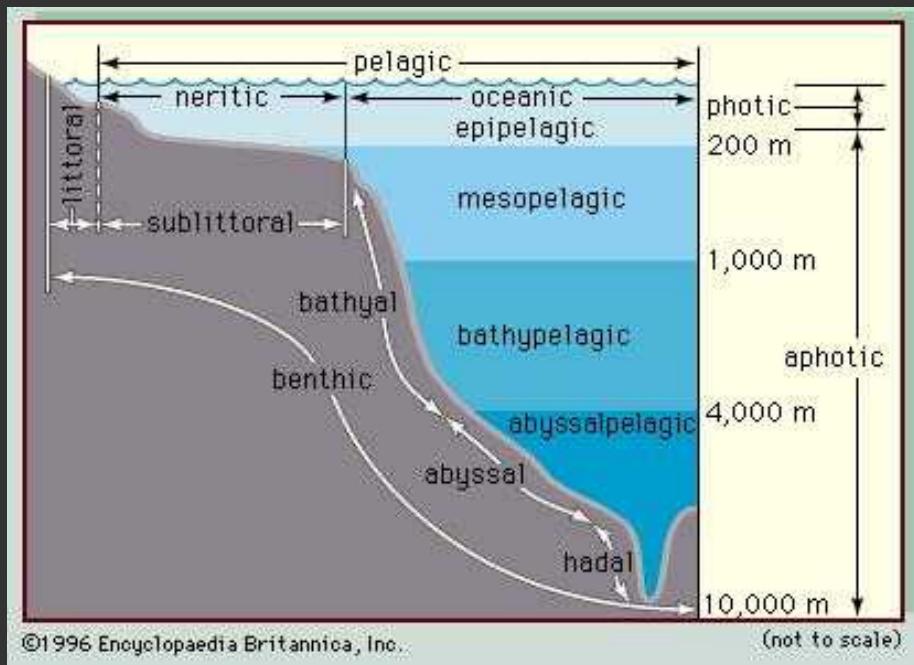
# River



# Coral Reef

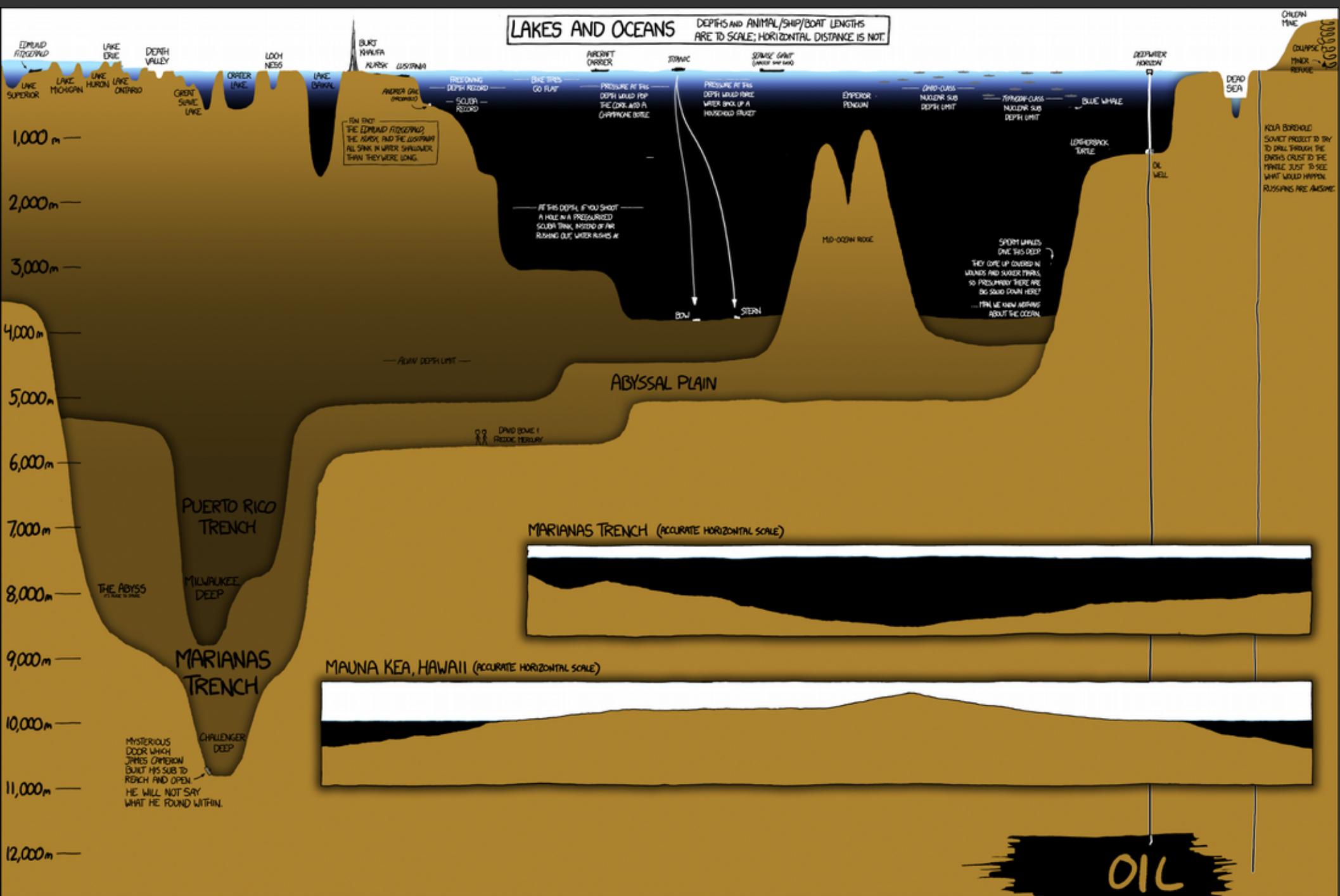


# Marine Pelagic

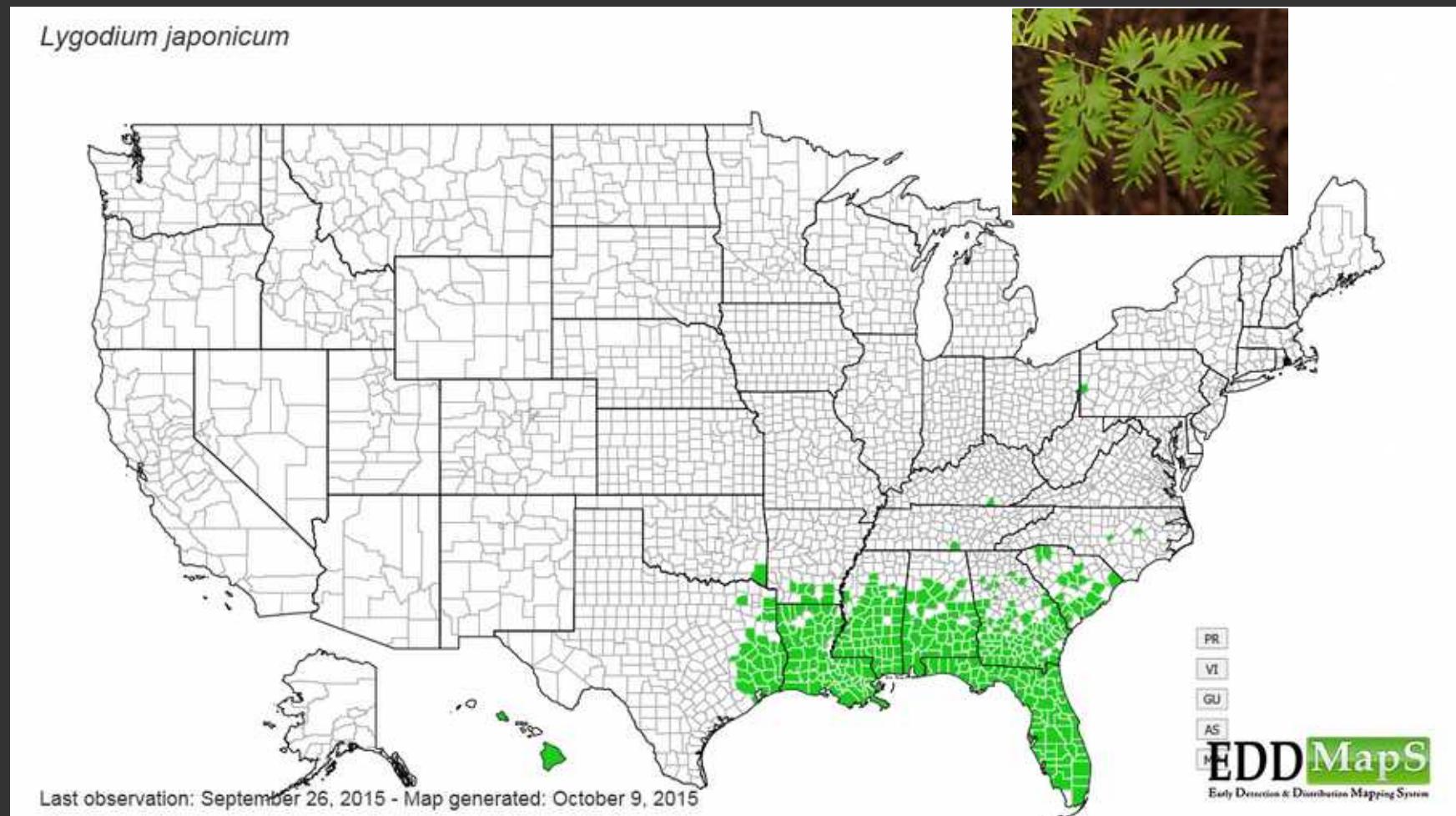


## LAKES AND OCEANS

DEPTHS AND ANIMAL/SHIP/BOAT LENGTHS  
ARE TO SCALE; HORIZONTAL DISTANCE IS NOT.

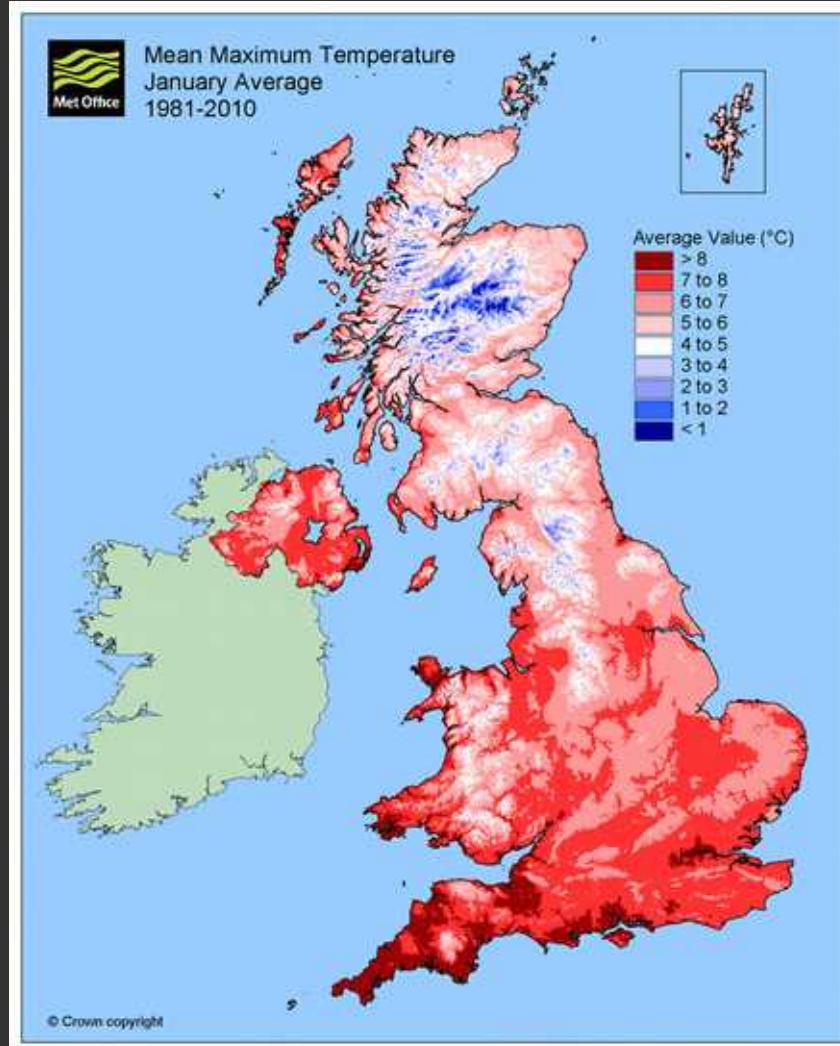


# Dispersal and Distribution



What limits species' distributions?

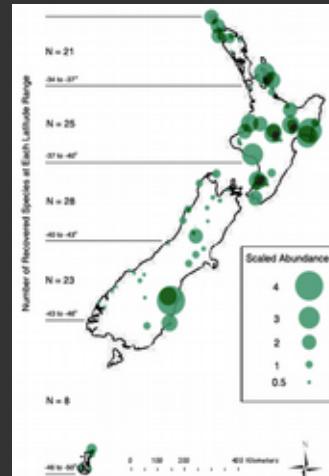
# Dispersal and Distribution



Skylark distribution in G.B.

# Factors that influence species' ranges

Dispersal adaptations / barriers

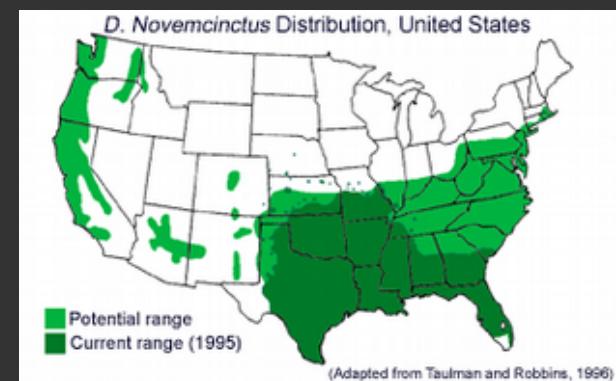


Niche availability

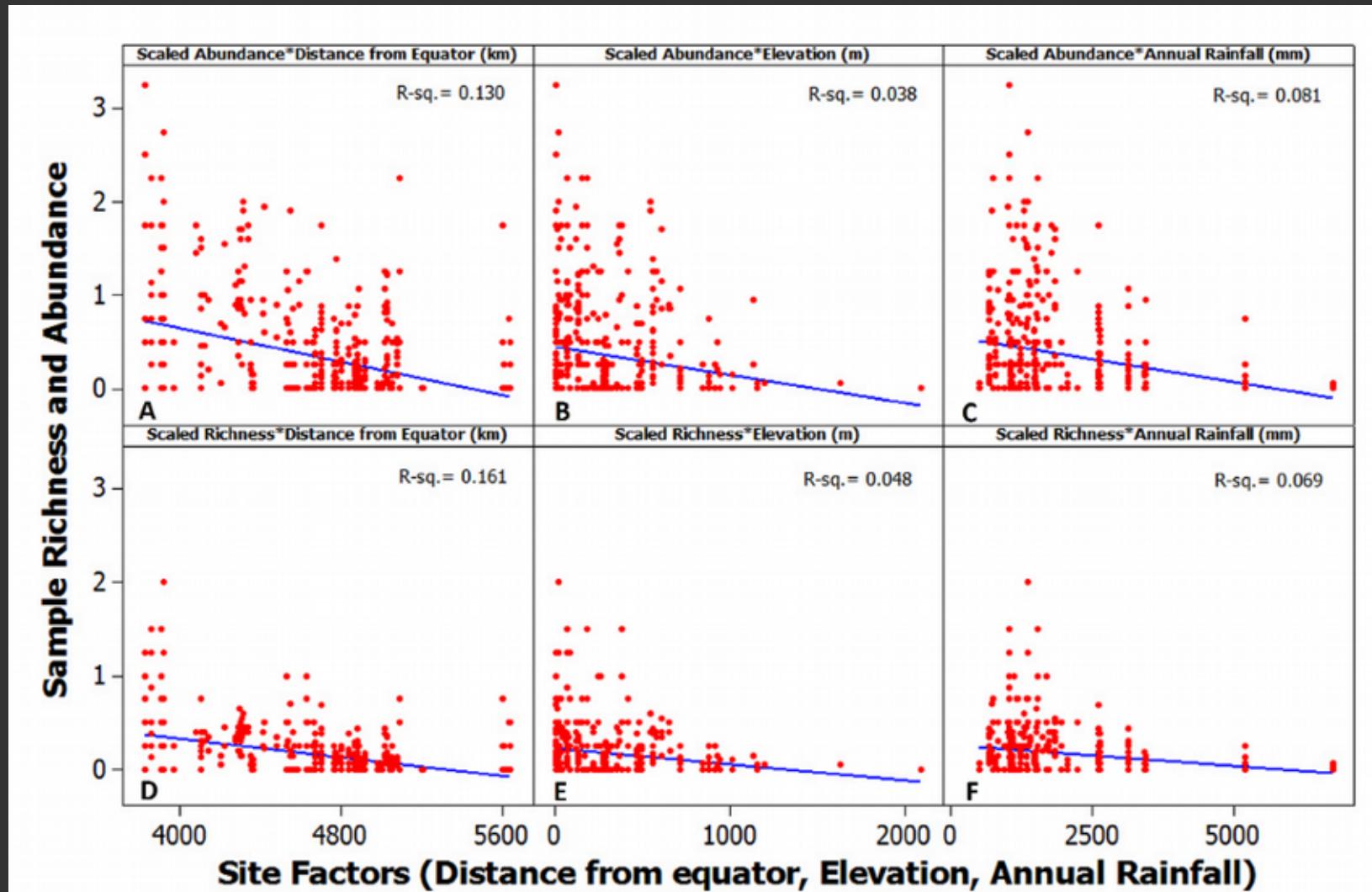
Humans (intentional or not)



Climate



# Location $\leftarrow \rightarrow$ Climate



# Population ecology



(a) Clumped



(b) Uniform

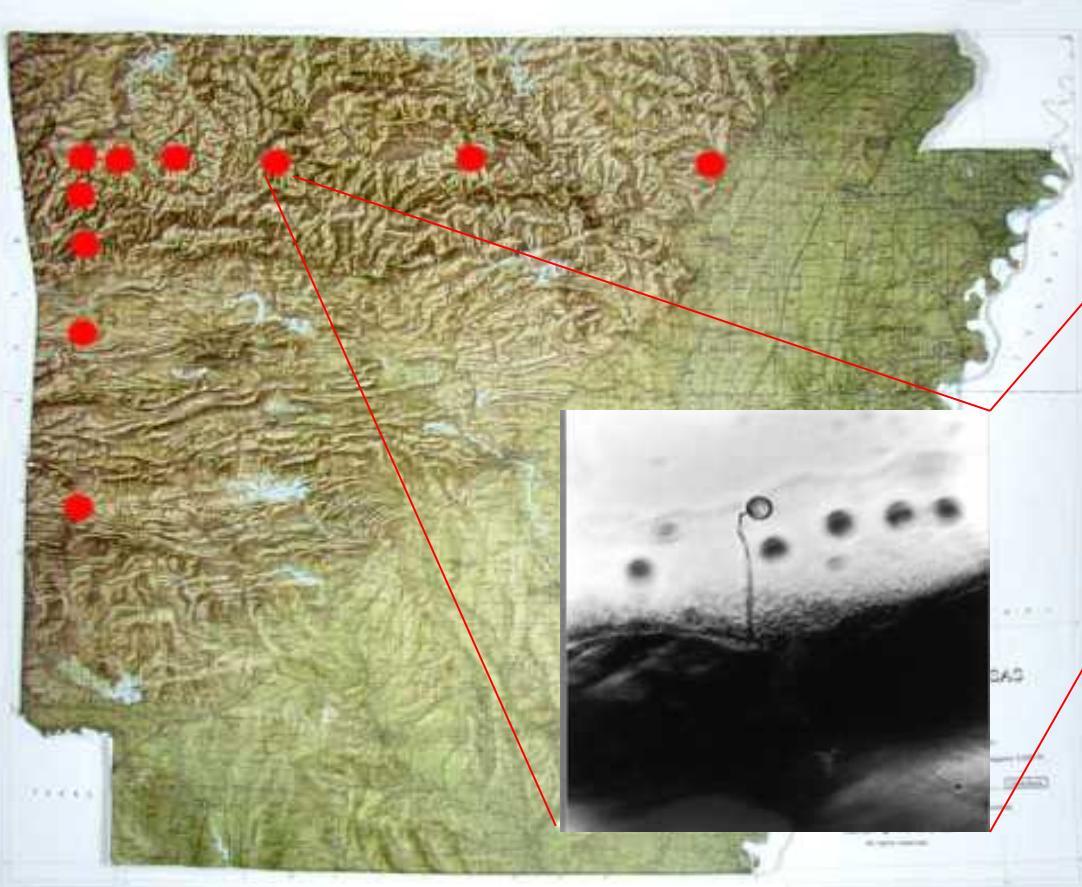


(c) Random

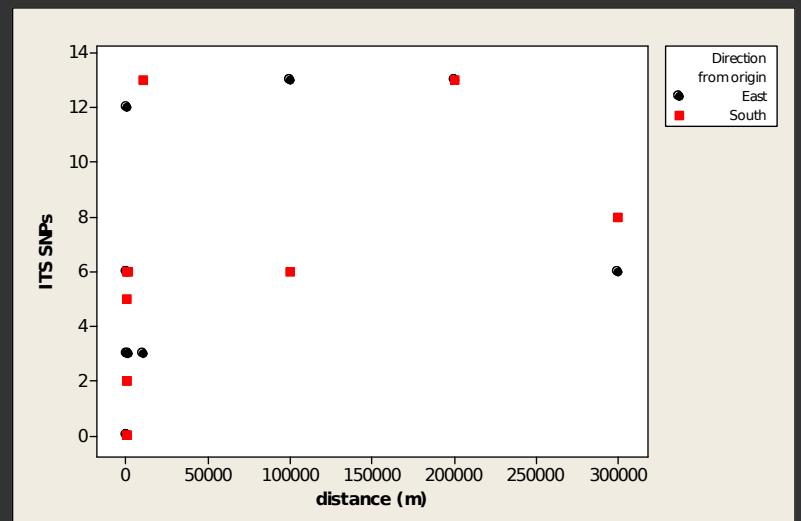
Group of same species in same area

How environment and genetics determines size and structure of populations

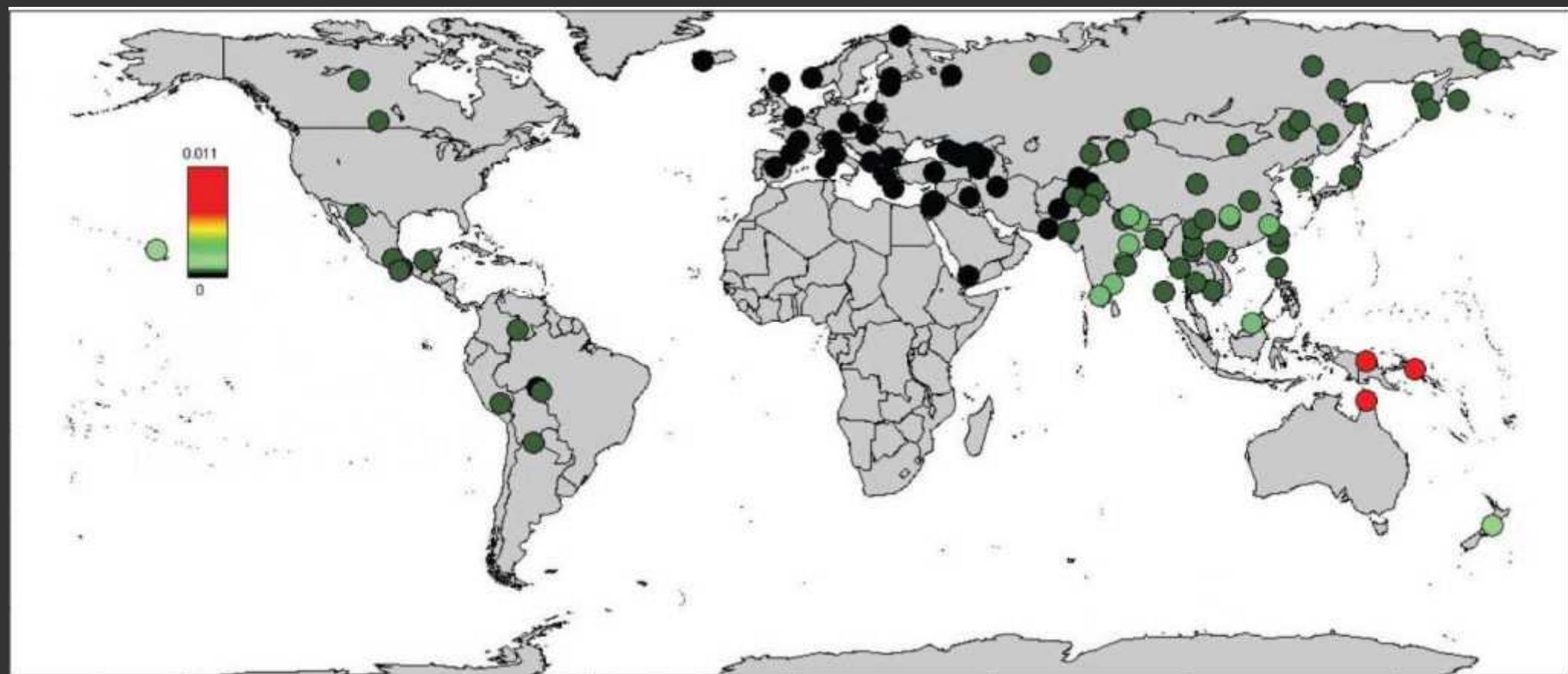
# Population genetics



18S rDNA + ITS1

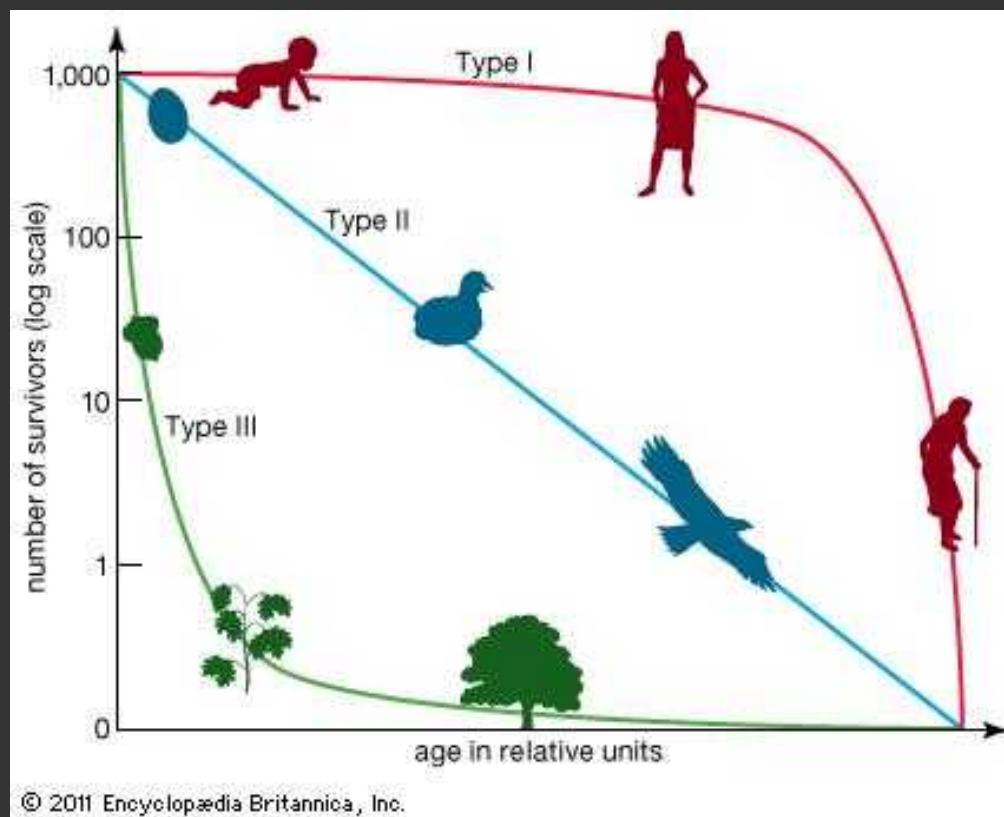


# Tracking specific Neanderthal genes in modern humans

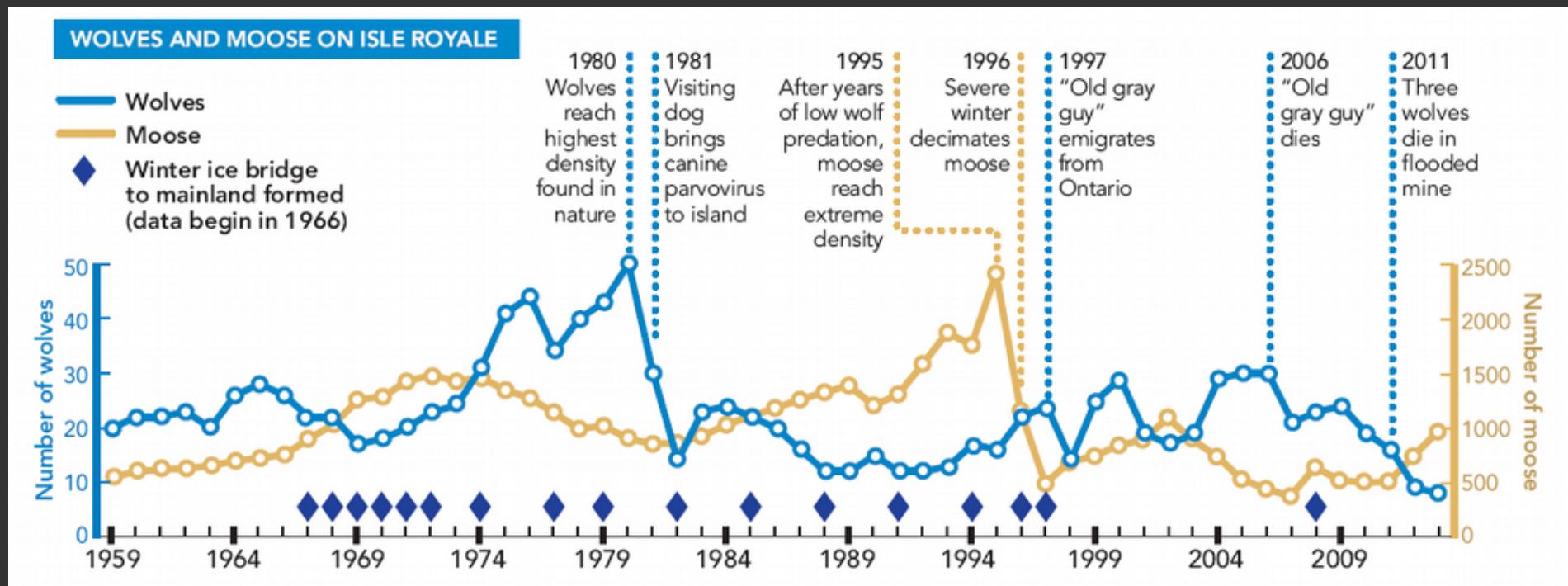
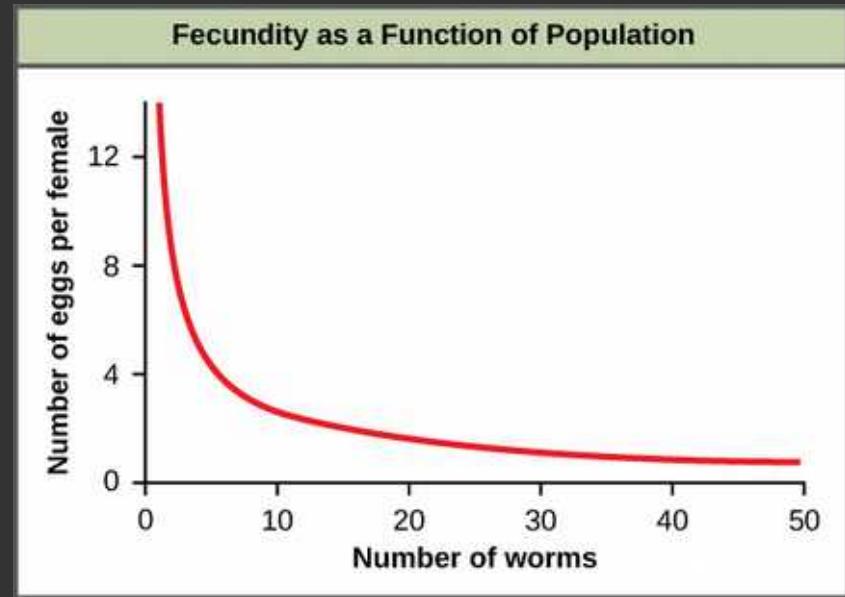
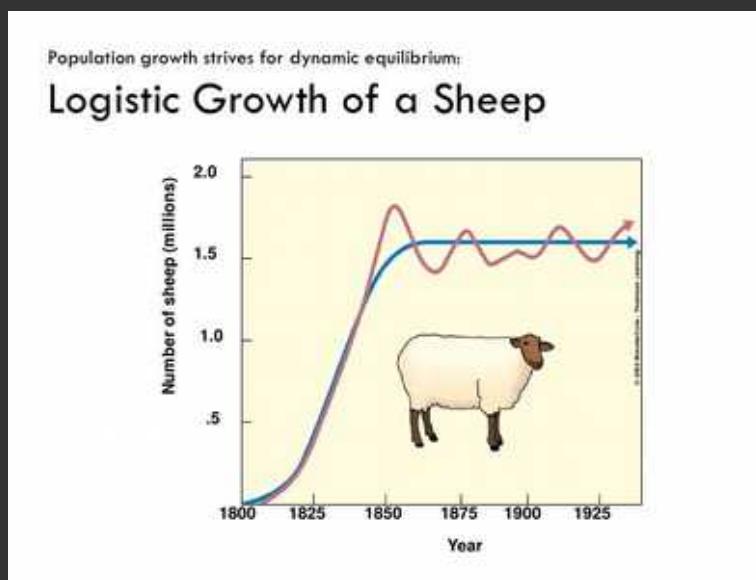


# Population demographics

Survivorship curves



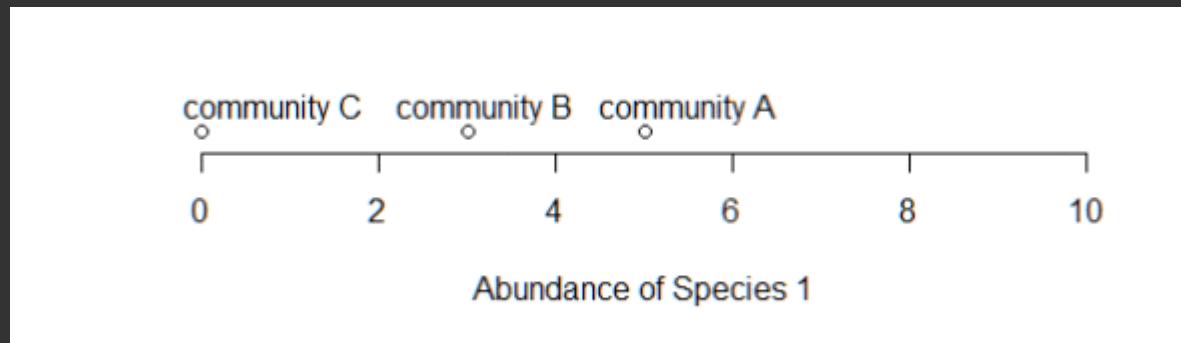
# What regulates population growth?



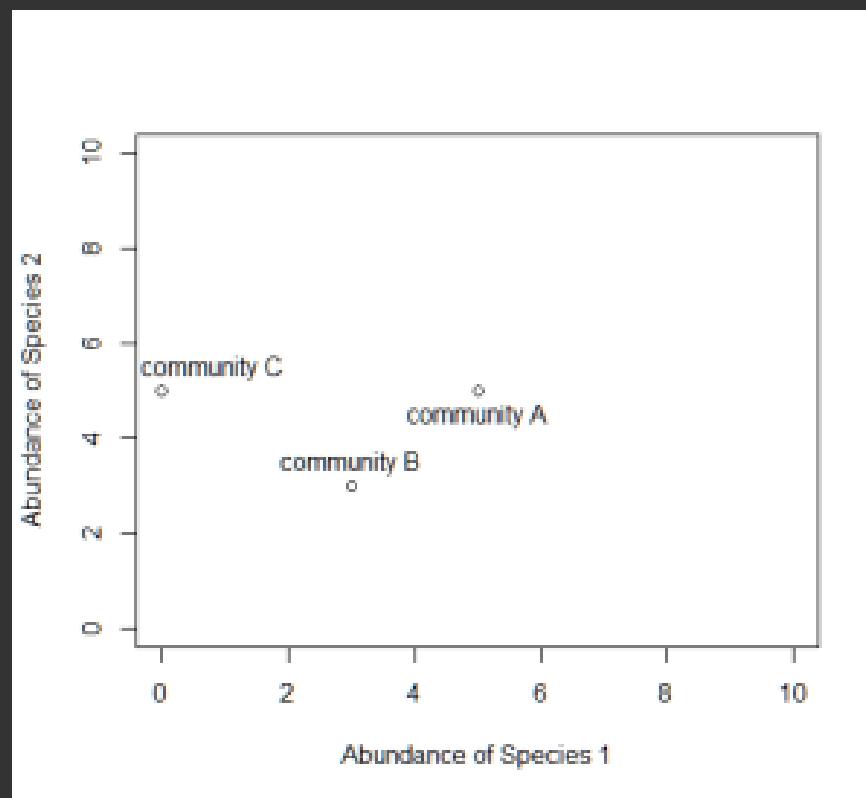


How do you compare whole communities across different places?

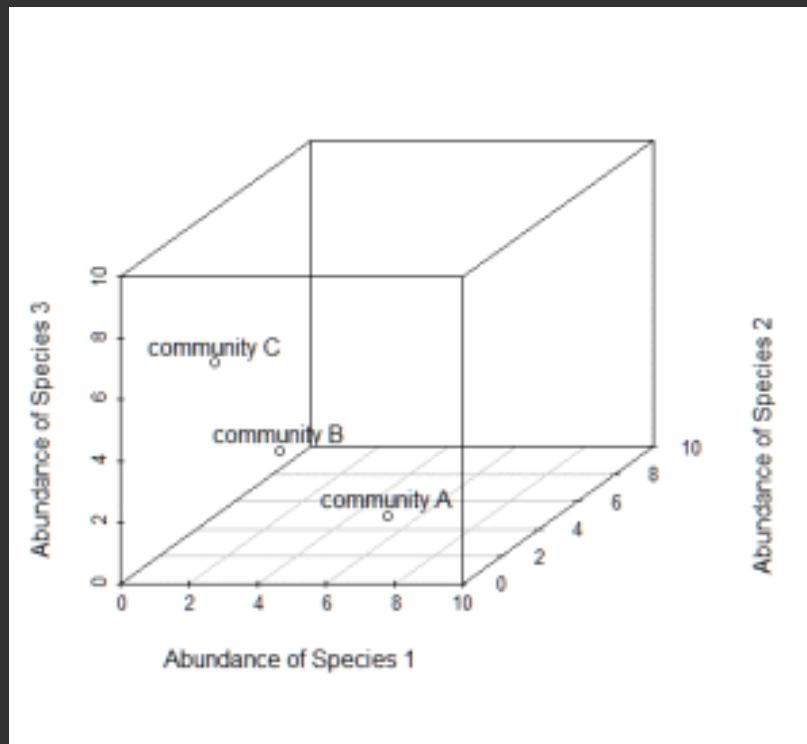
# Consider communities of only a single species



# Now consider communities of two species



# How about communities with 3 species?



Now imagine as many axes as there are species  
in each community

Now imagine as many axes as there are species  
in each community























