# Ecology

**Study of interactions between organisms and environment**

Organisms
Populations
Communities
Ecosystems
Landscapes
Global

Increasing scale and complexity

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Climate

Biomes

Ecological change ⇄ Evolutionary change

Controllers of species' distributions

# What is an “environment?”

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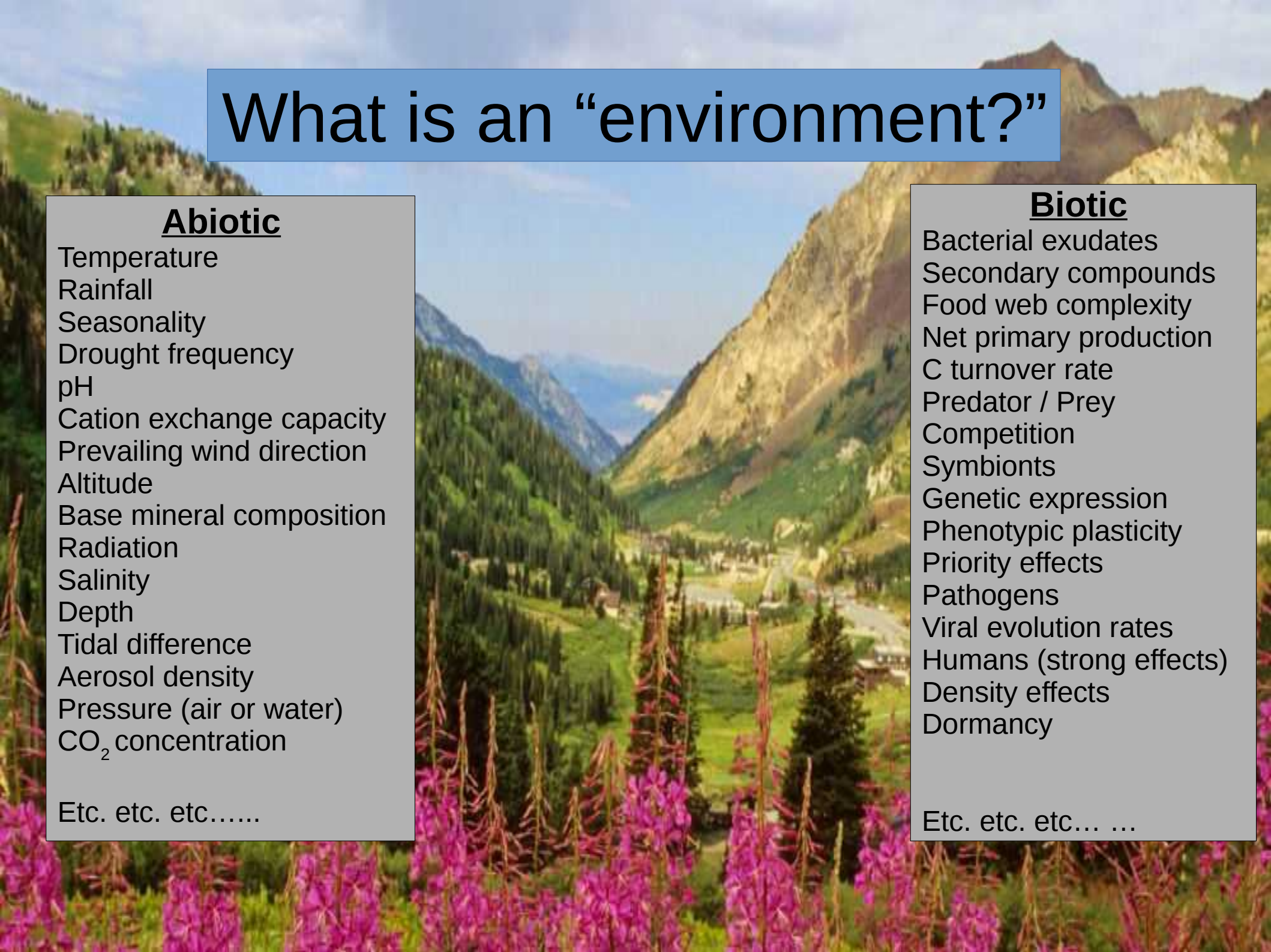


**Abiotic**

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)
$CO_2$ concentration

Etc. etc. etc……

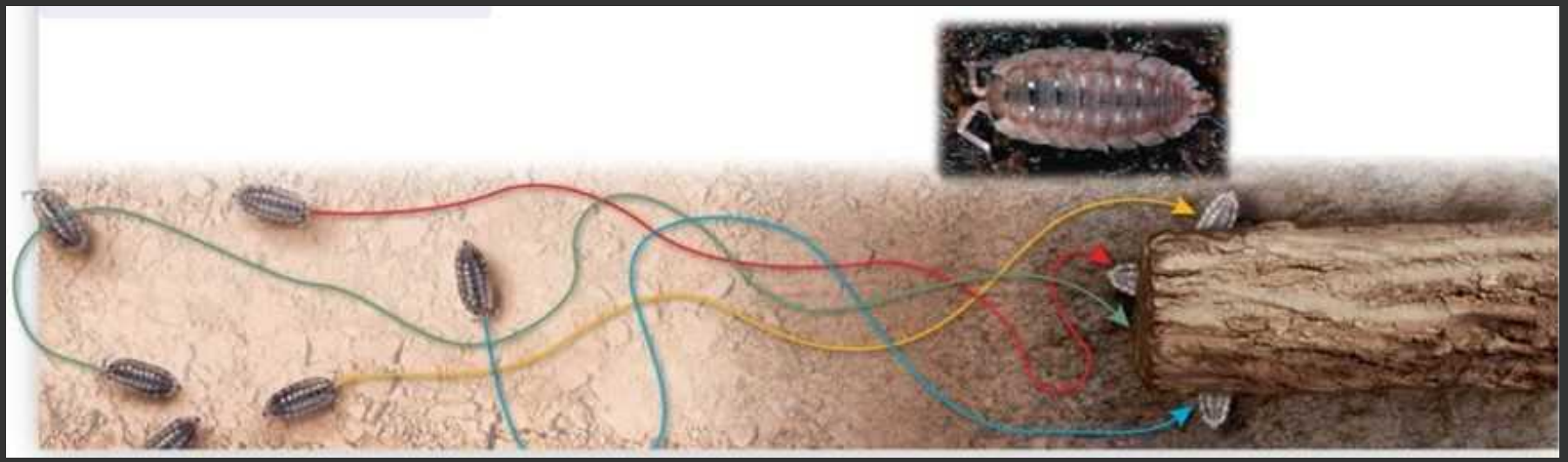
**Biotic**

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

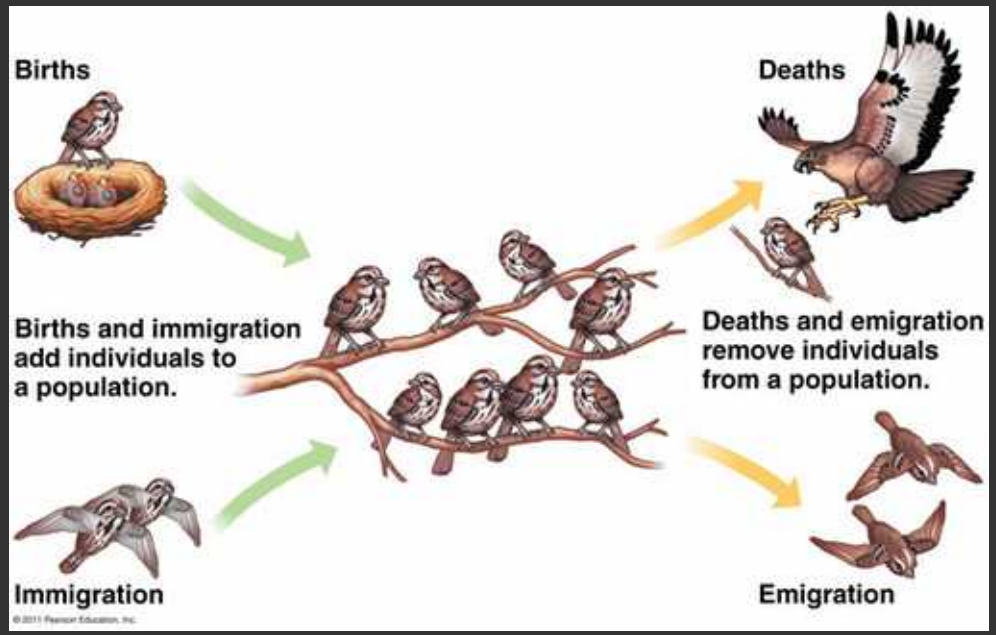


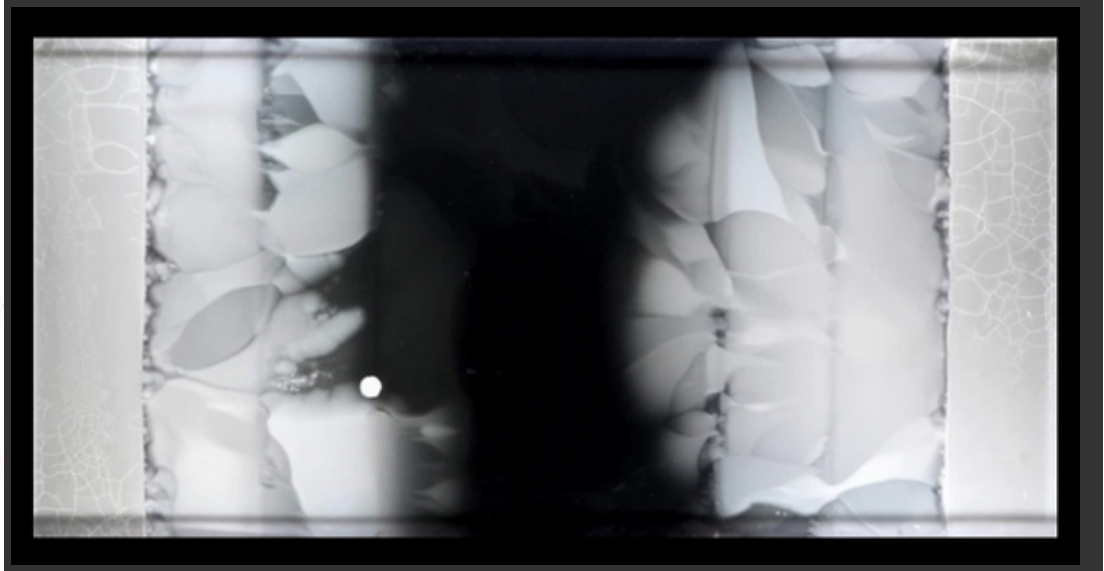
# Organismal Ecology

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

# Population Ecology

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



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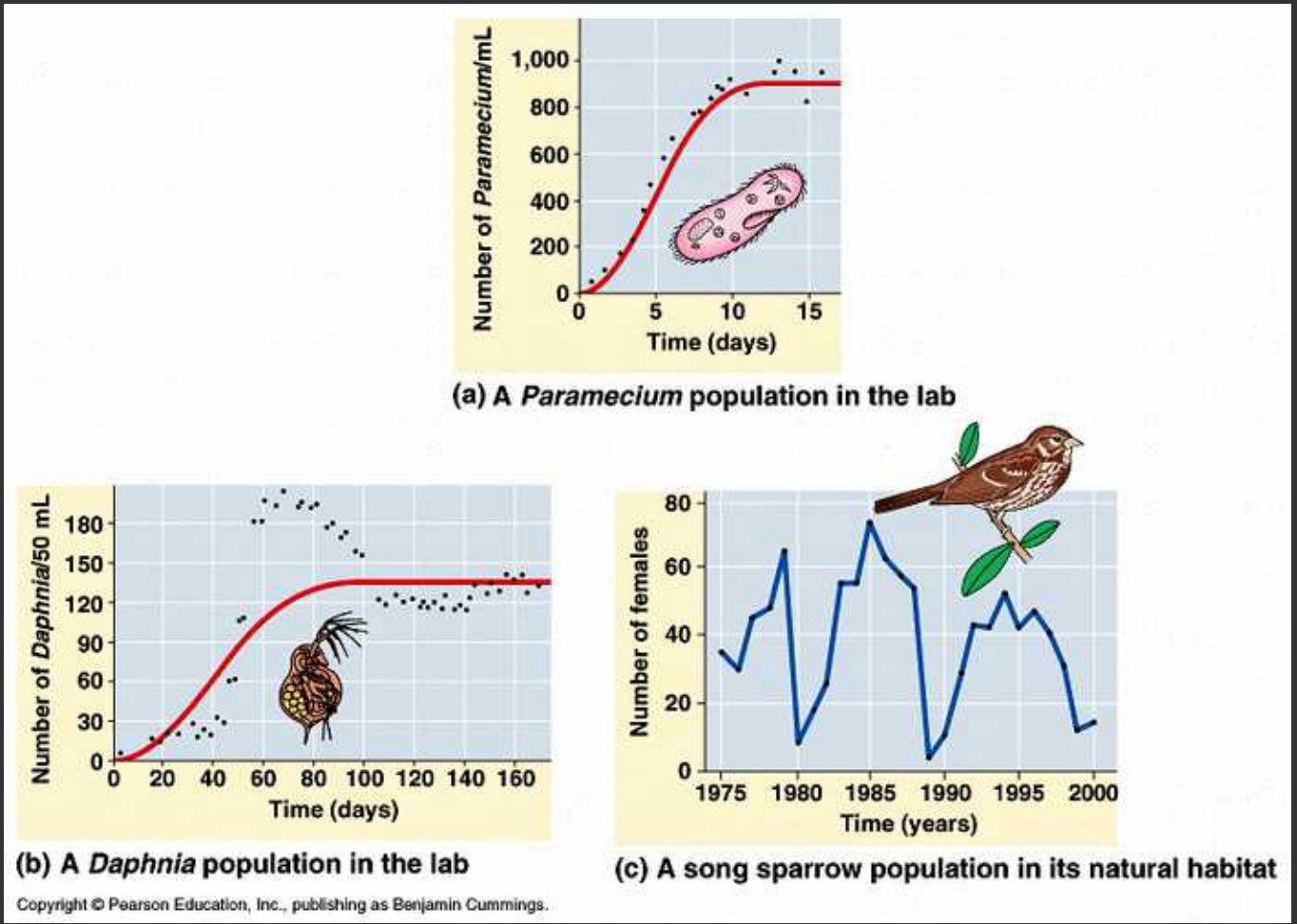
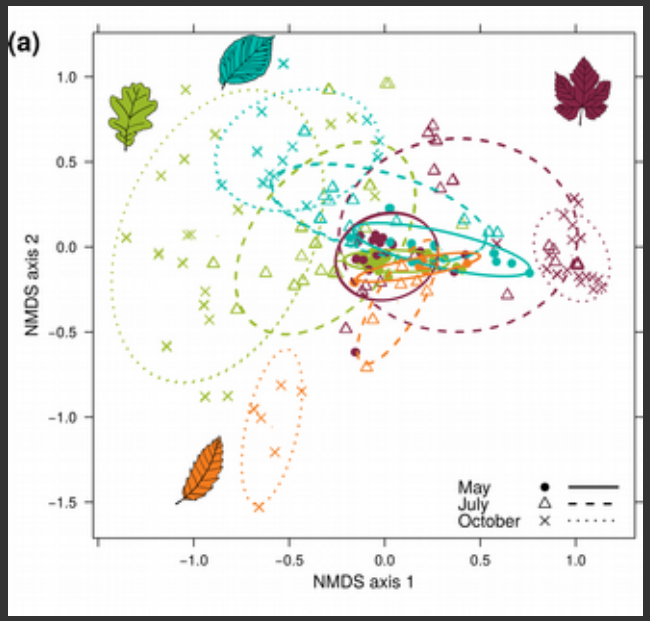
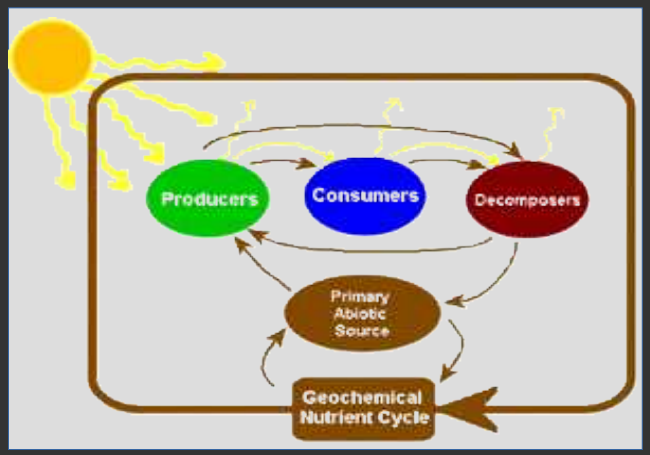
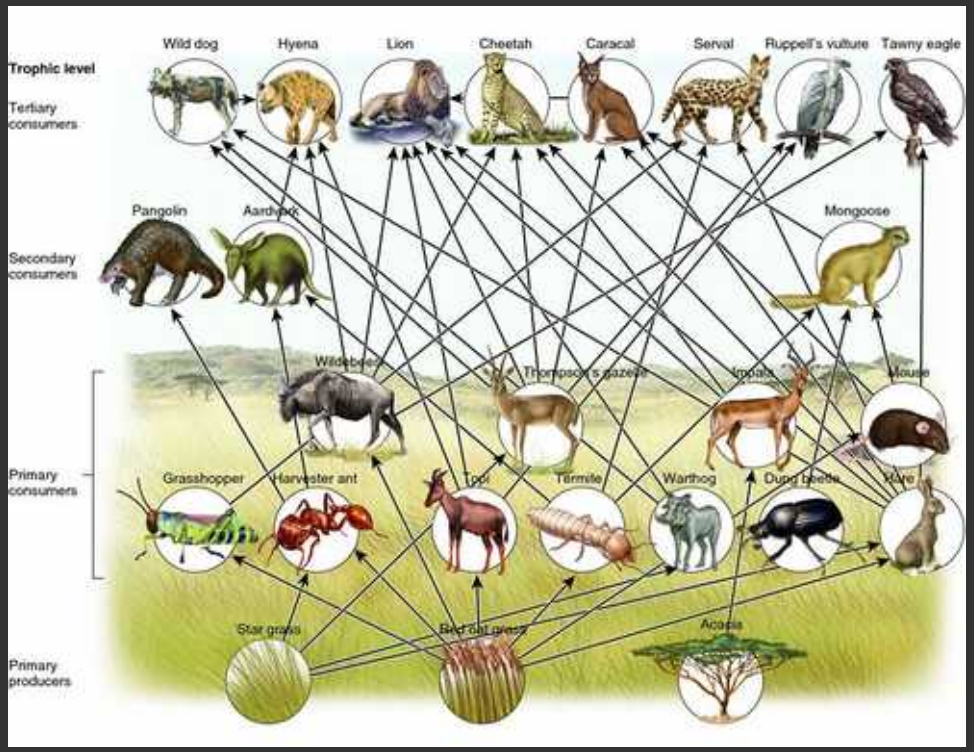


# Community Ecology

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



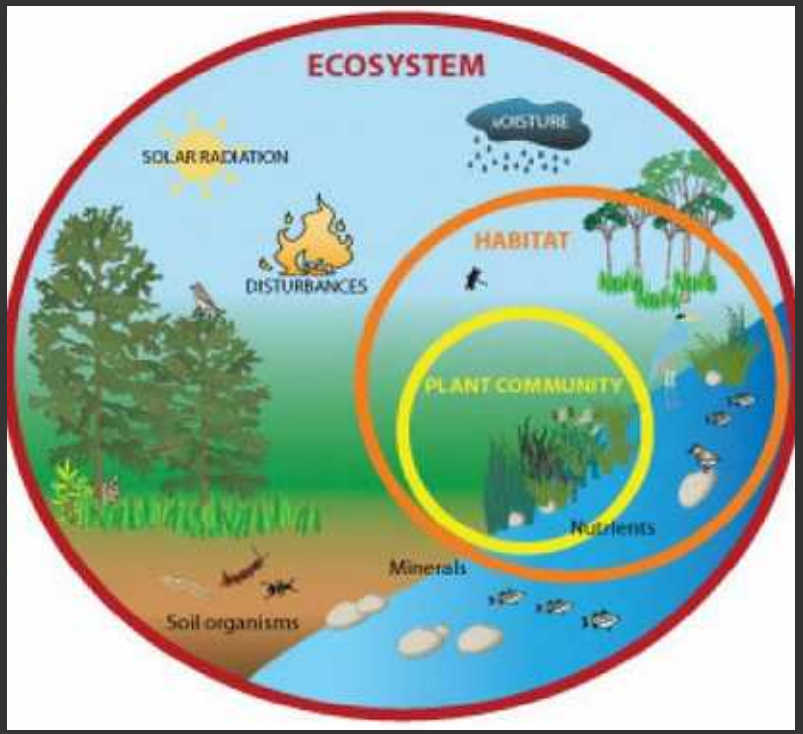



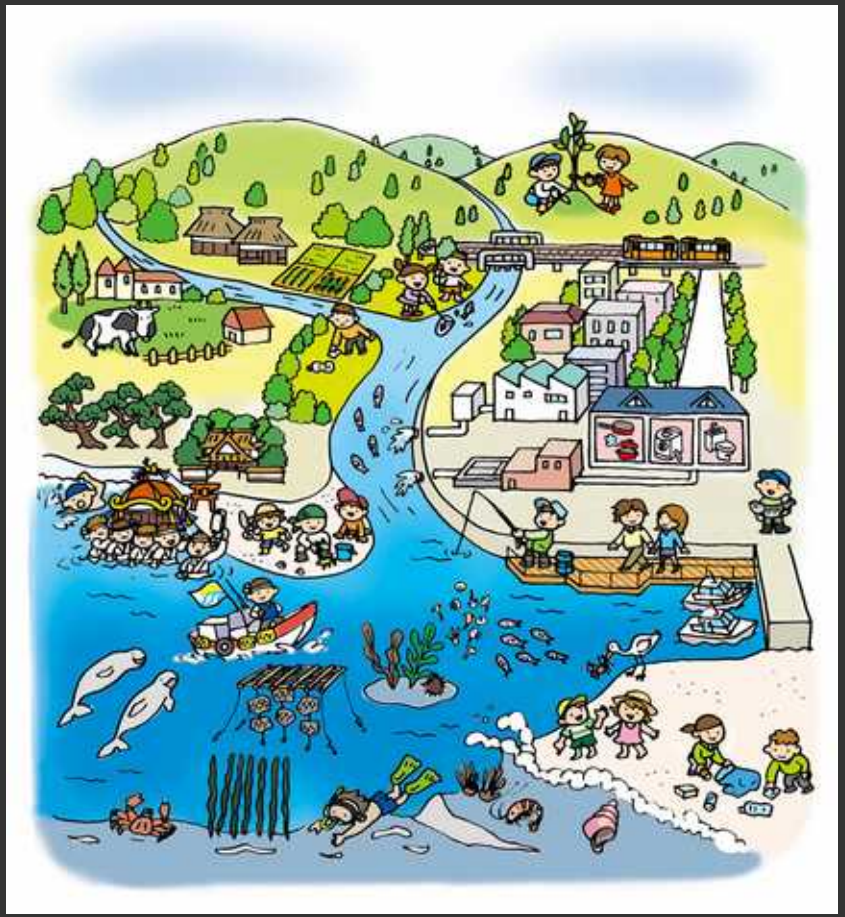
# Community Ecology

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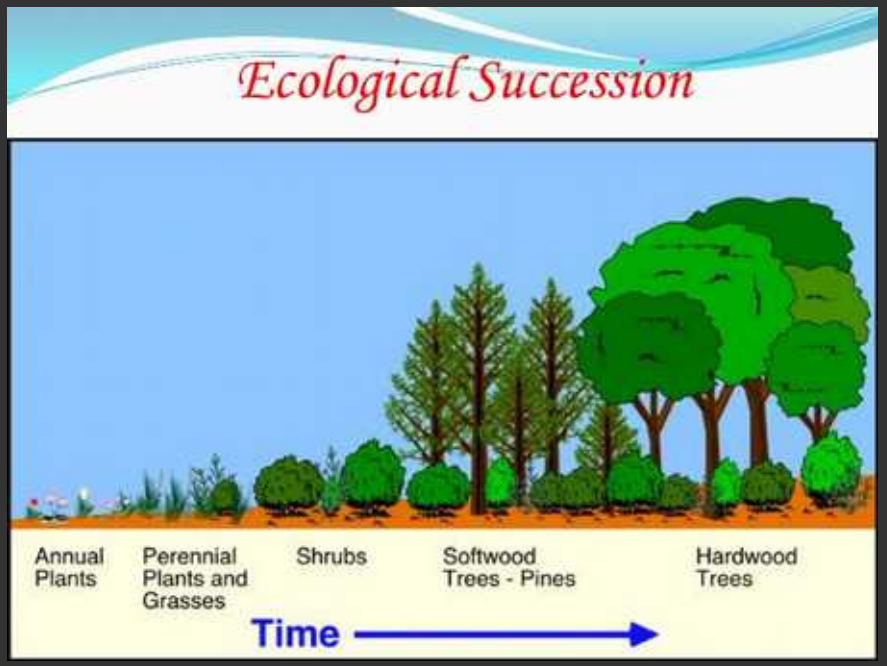
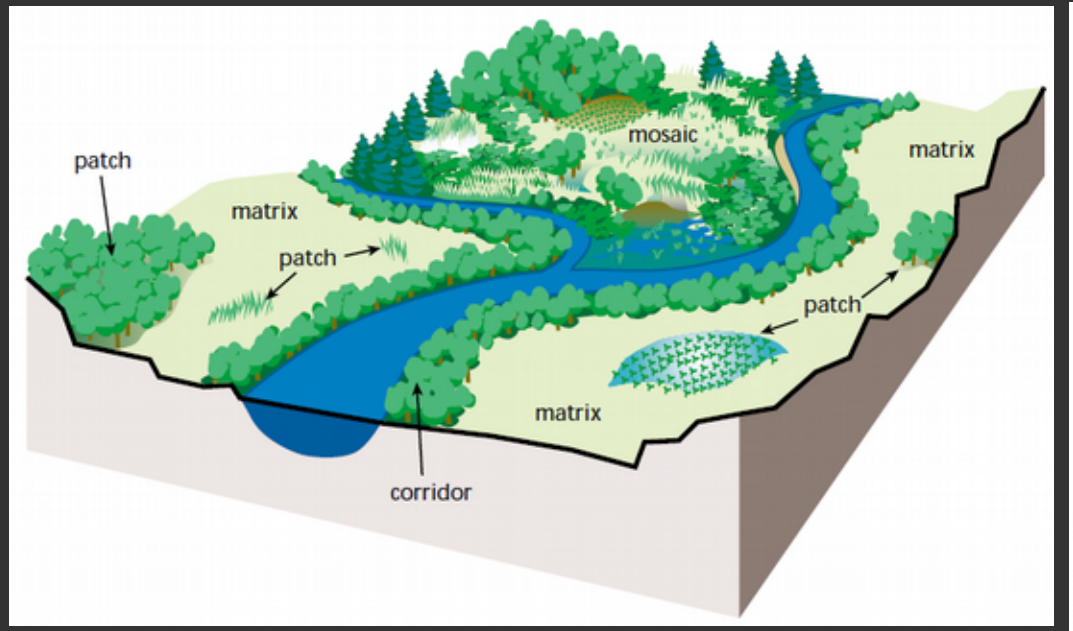
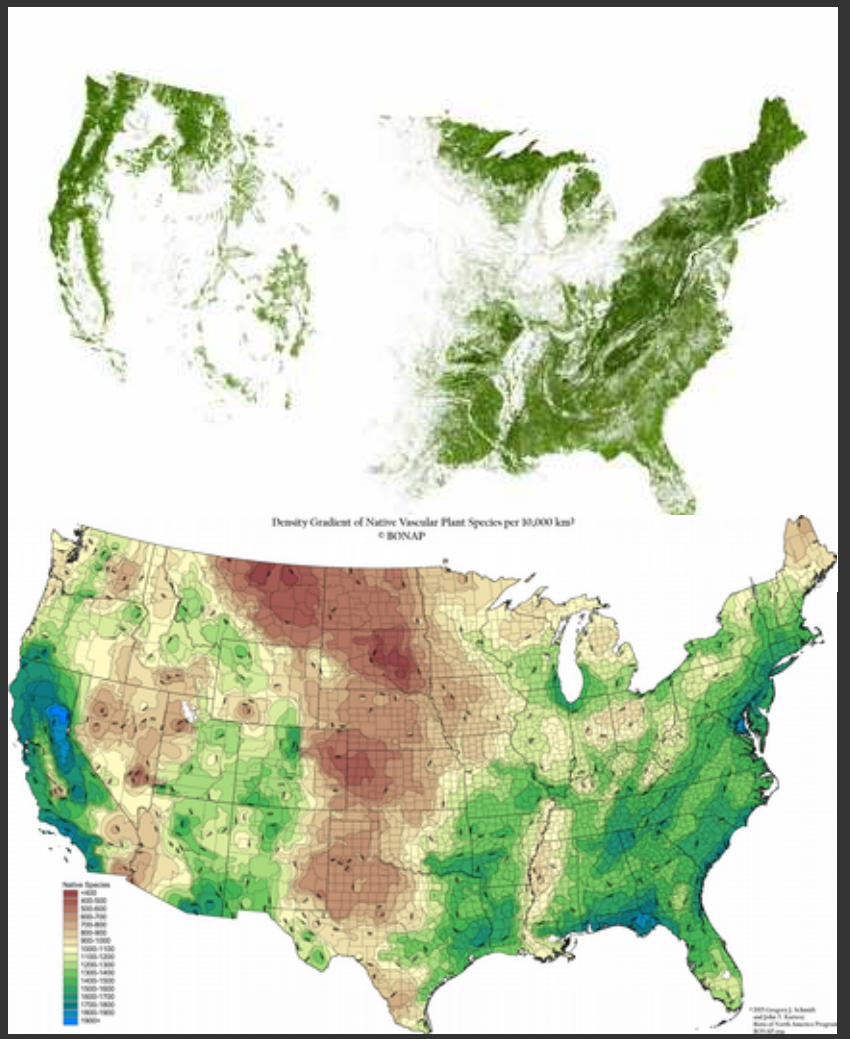
Flow of energy and elements between populations and communities and environment at ecosystem scale




# Landscape Ecology

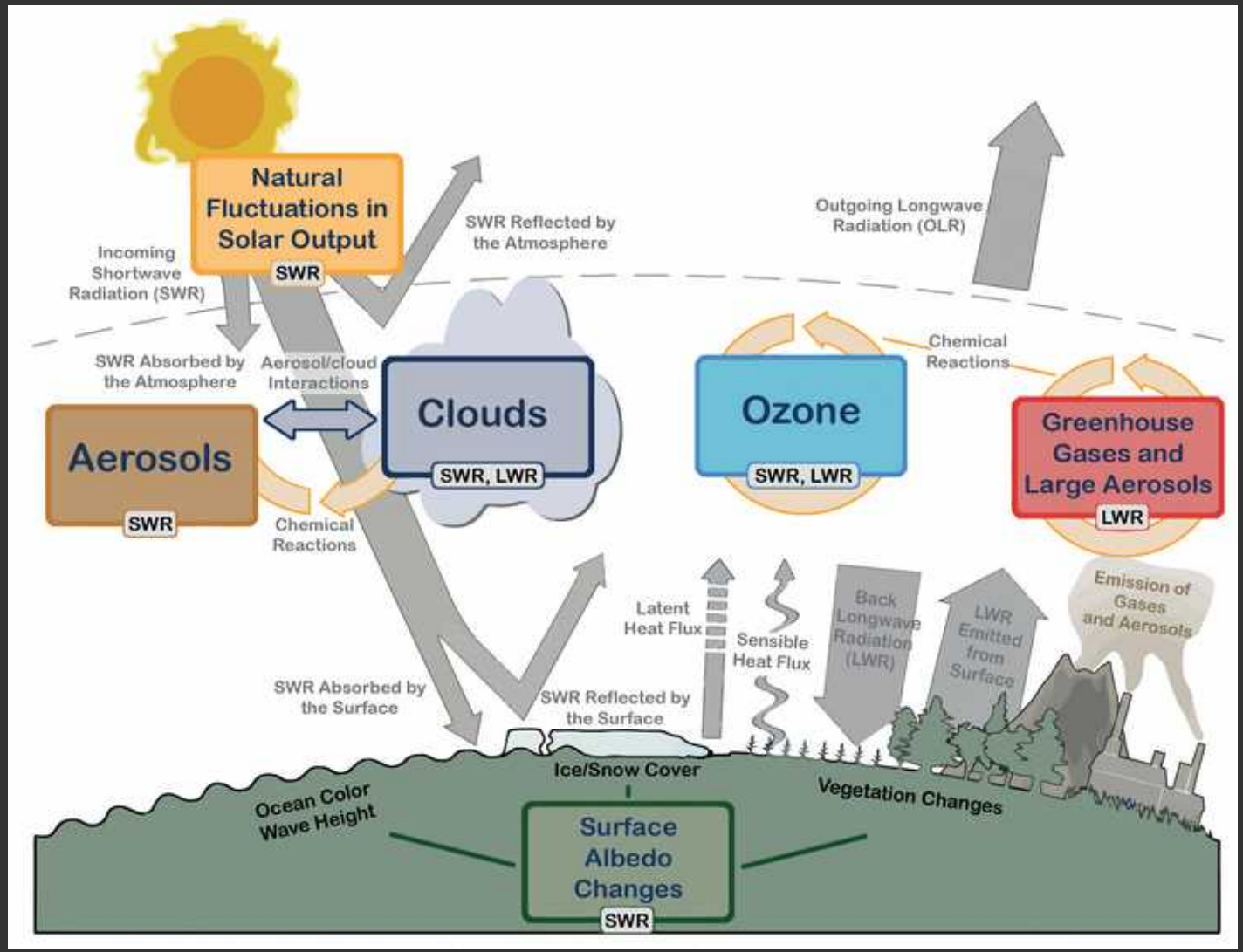
Flow of energy and elements between populations and communities and environment at landscape scale (multiple adjoining ecosystems)



# Global Ecology

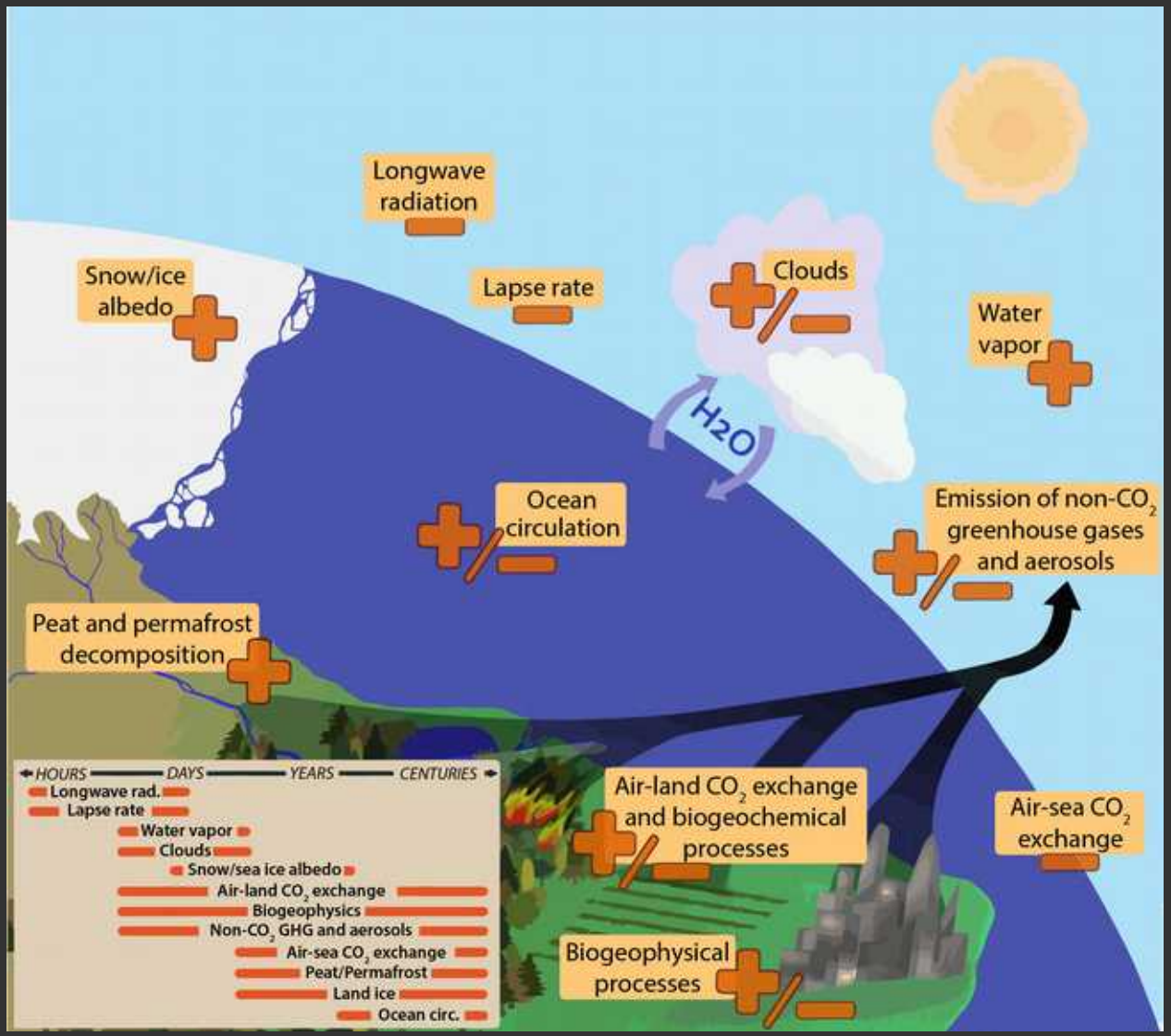
Flow of energy and elements between populations and communities and environment at biosphere scale (whole freaking Earth)




IPCC AR5 Fig 1_2

# Global Ecology

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




IPCC AR5 Fig 1_1

# Biogeochemistry

Geophysics + Biology + Chemistry =

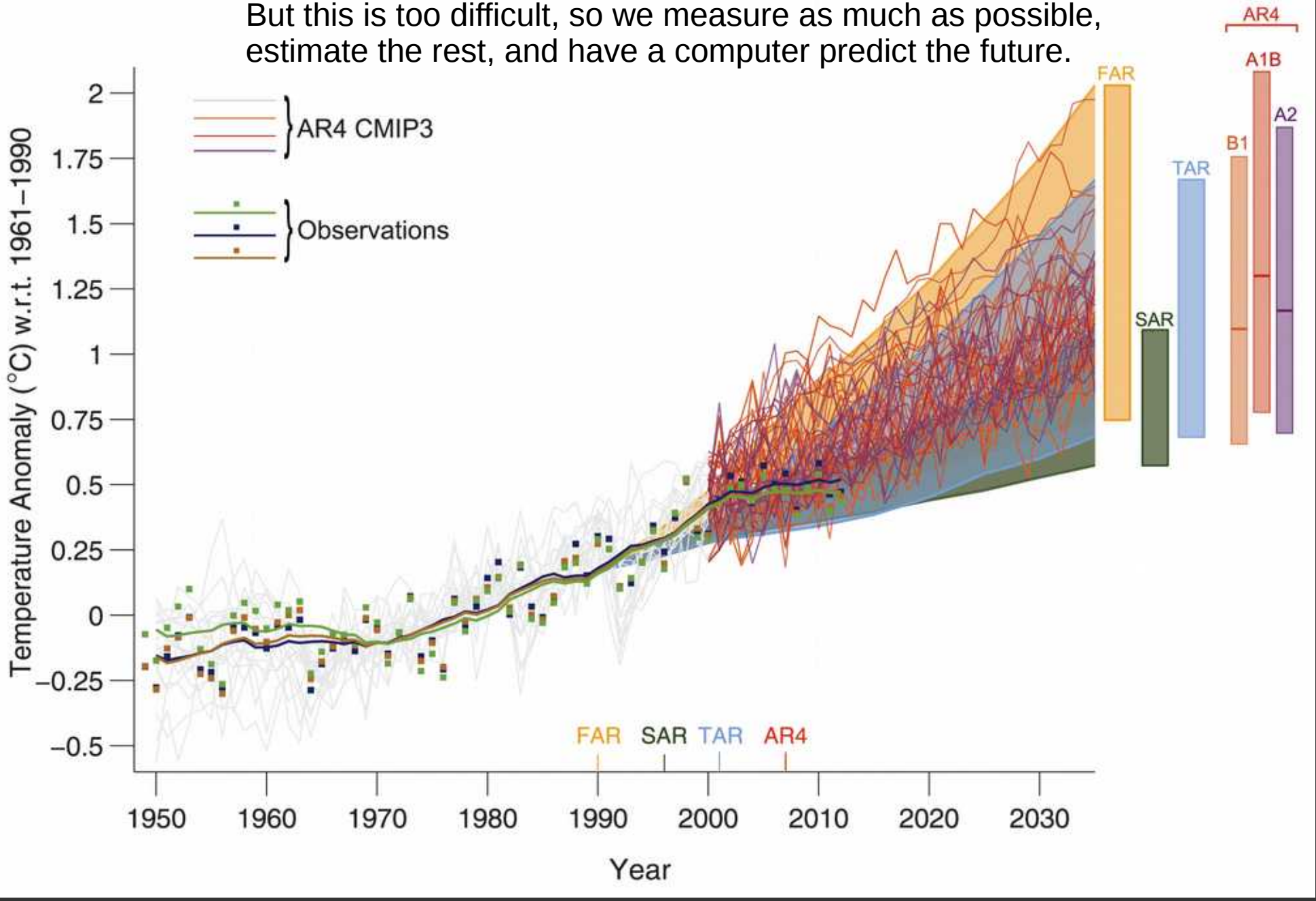
The bad@$$ crazy sum of all awesomeness!

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.

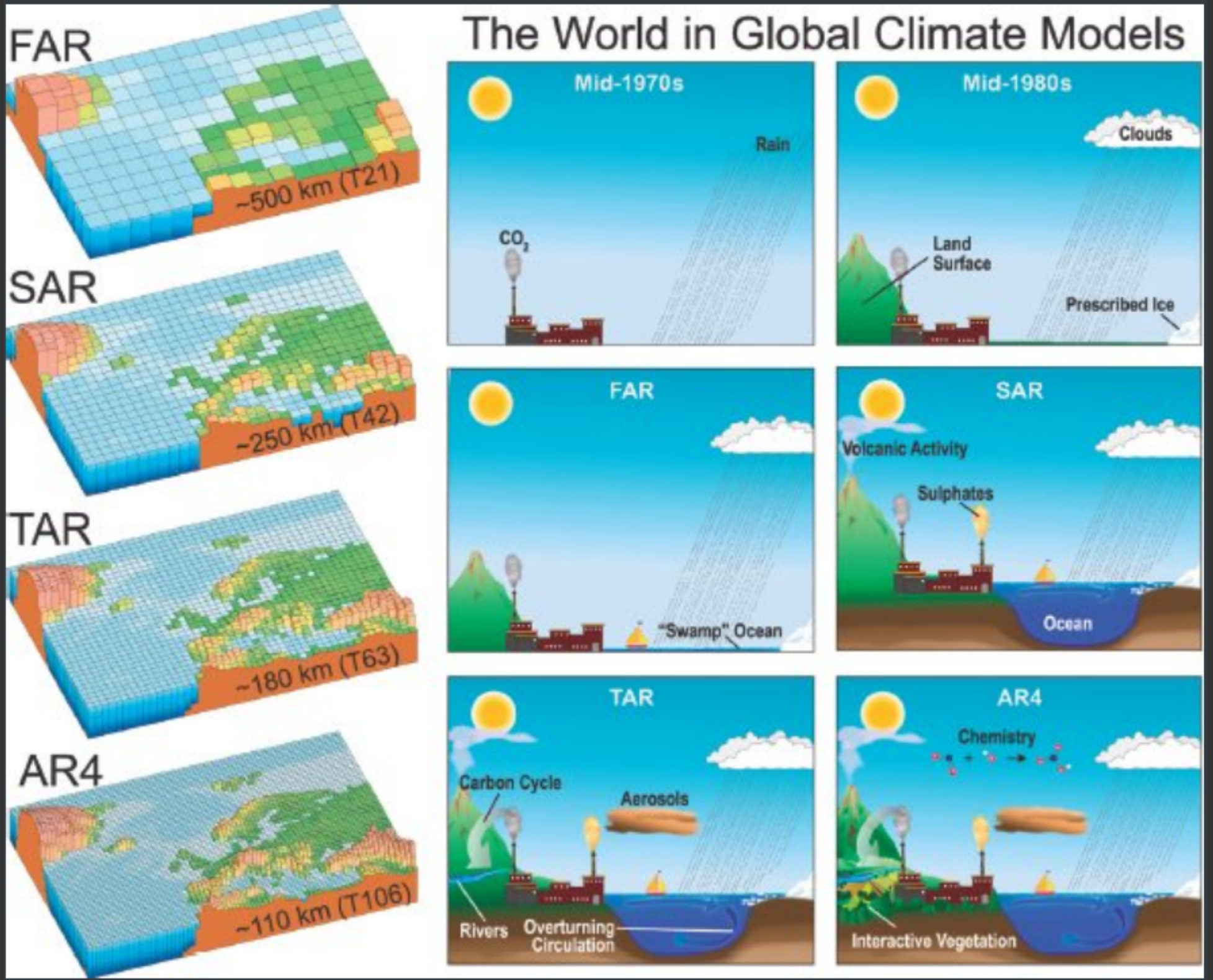
If you know <u>everything</u> about an environment (pH, sunlight, soil density, primary productivity, everything) …

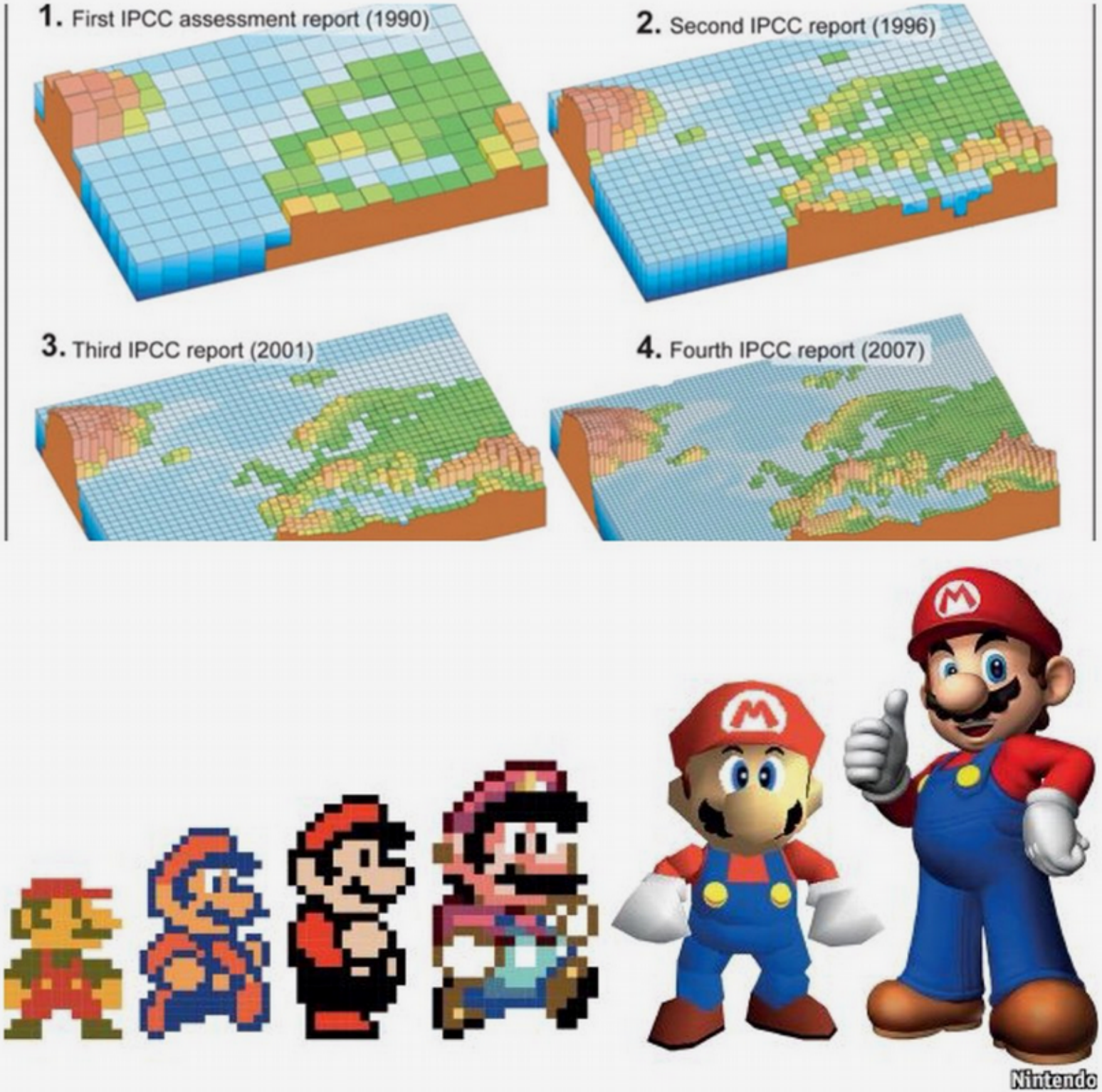
... then the genomes present in that environment could theoretically allow you to predict the future with perfect accuracy!

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

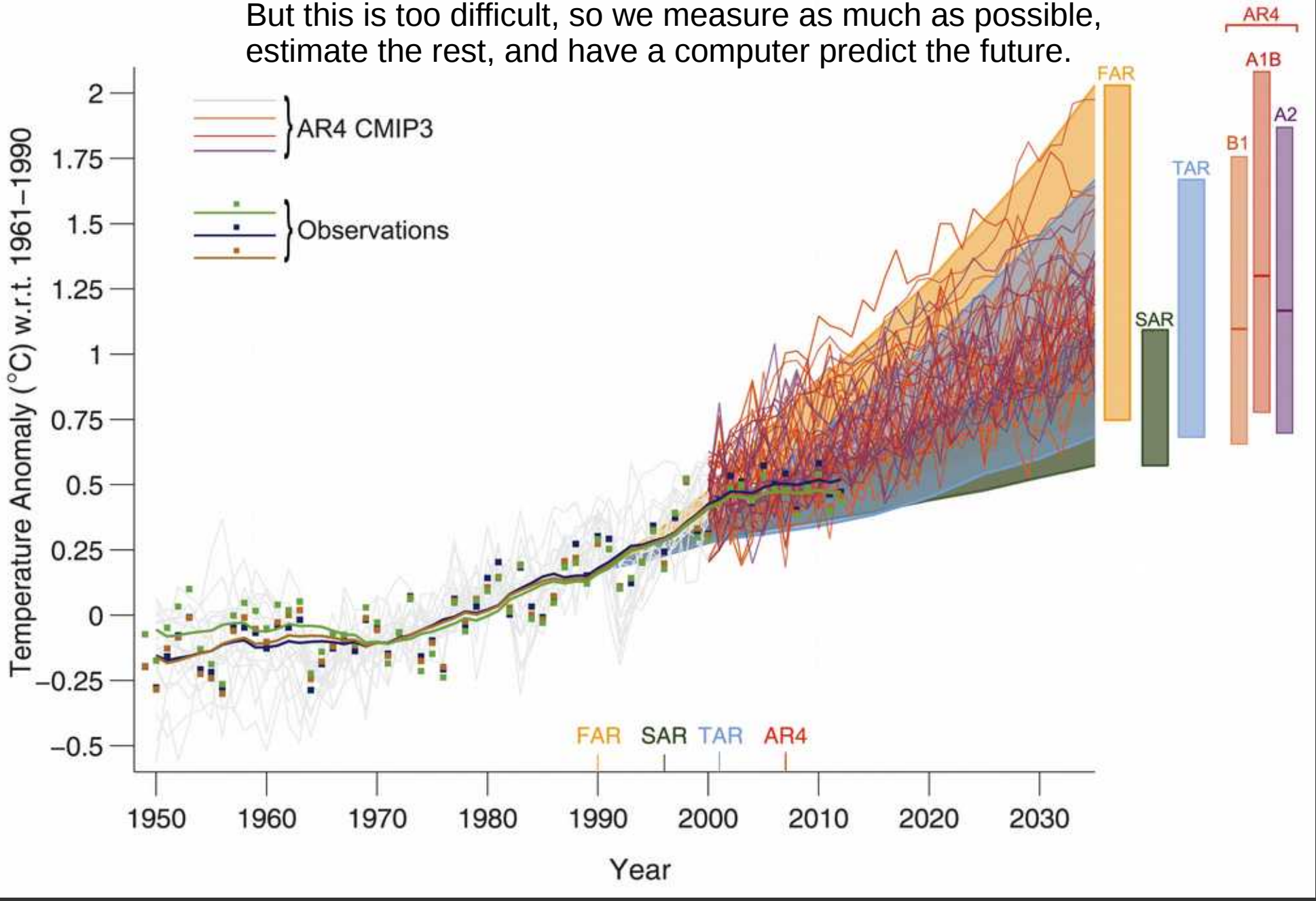



IPCC AR-5 Fig 1_4


FAR
~500 km (T21)
SAR
~250 km (T42)
TAR
~180 km (T63)
AR4
~110 km (T106)
The World in Global Climate Models
Mid-1970s
Rain
$CO_2$
Mid-1980s
Clouds
Land Surface
Prescribed Ice
FAR
"Swamp" Ocean
SAR
Volcanic Activity
Sulphates
Ocean
TAR
Carbon Cycle
Aerosols
Rivers
Overturning Circulation
AR4
Chemistry
Interactive Vegetation


1. First IPCC assessment report (1990)
2. Second IPCC report (1996)
3. Third IPCC report (2001)
4. Fourth IPCC report (2007)
Nintendo

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



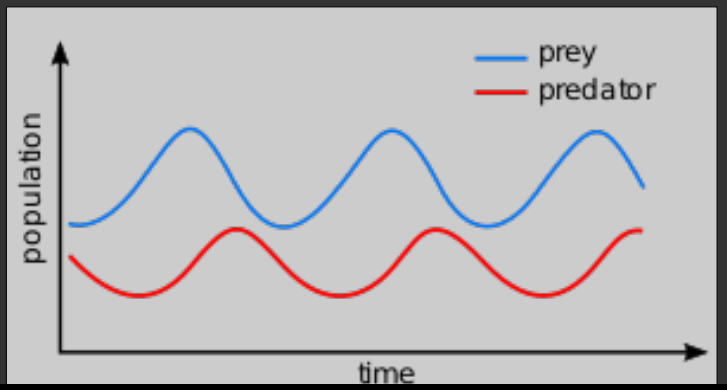

IPCC AR-5 Fig 1_4

# 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

$$\frac{dX}{dt} = \alpha . X - \beta . X . Y$$
$$\frac{dY}{dt} = \gamma . \beta . X . Y - \delta . Y$$




- $X$ 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:

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

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:

$$H_{t+1} = k H_t e^{-a P_t}$$
$$P_{t+1} = c H_t \left(1 - e^{-a P_t}\right)$$

# Ecological modeling

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

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

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

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

Projected uncertainty

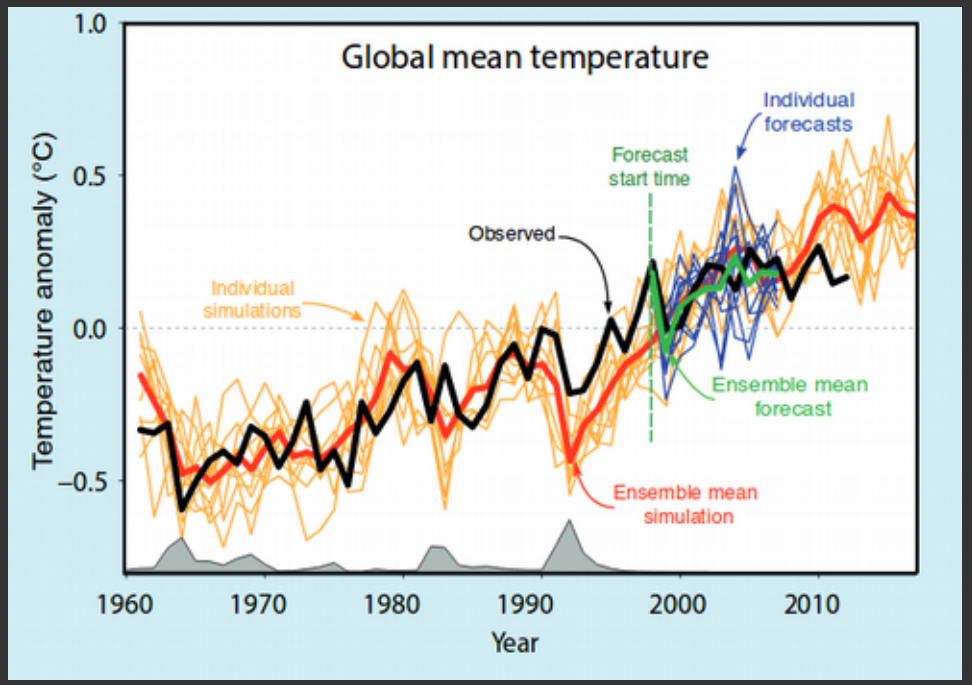
$$f_\Theta(\Theta)\propto\frac{1}{\theta_1}\prod_{j=2}^{m}\theta_{j-1}\exp(-\theta_j/\theta_{j-1}).$$

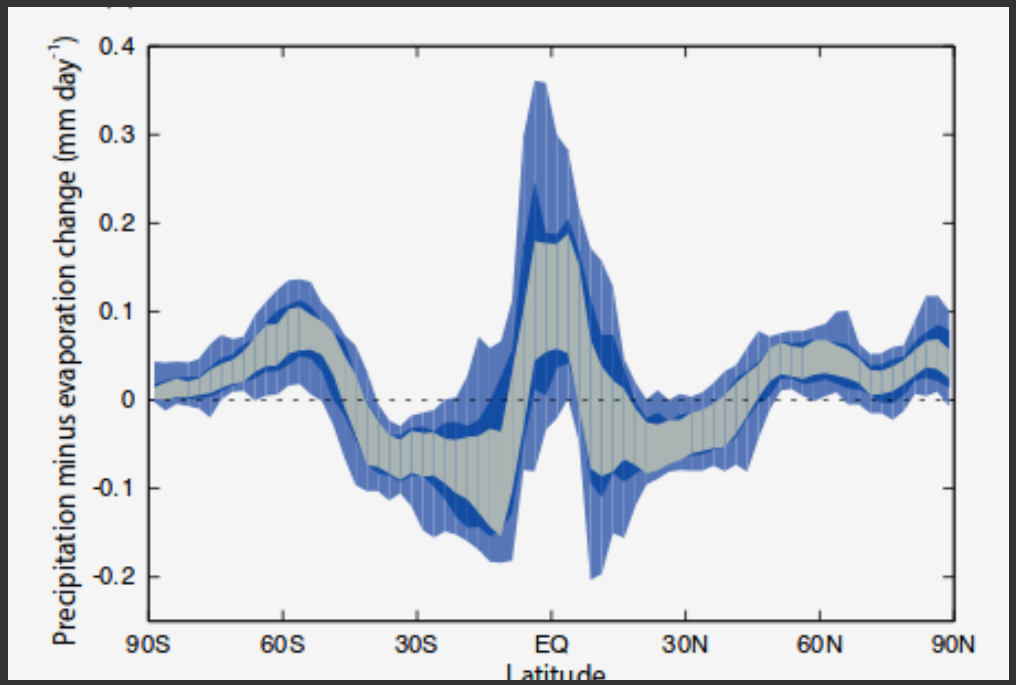
Distribution of uncertainty

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

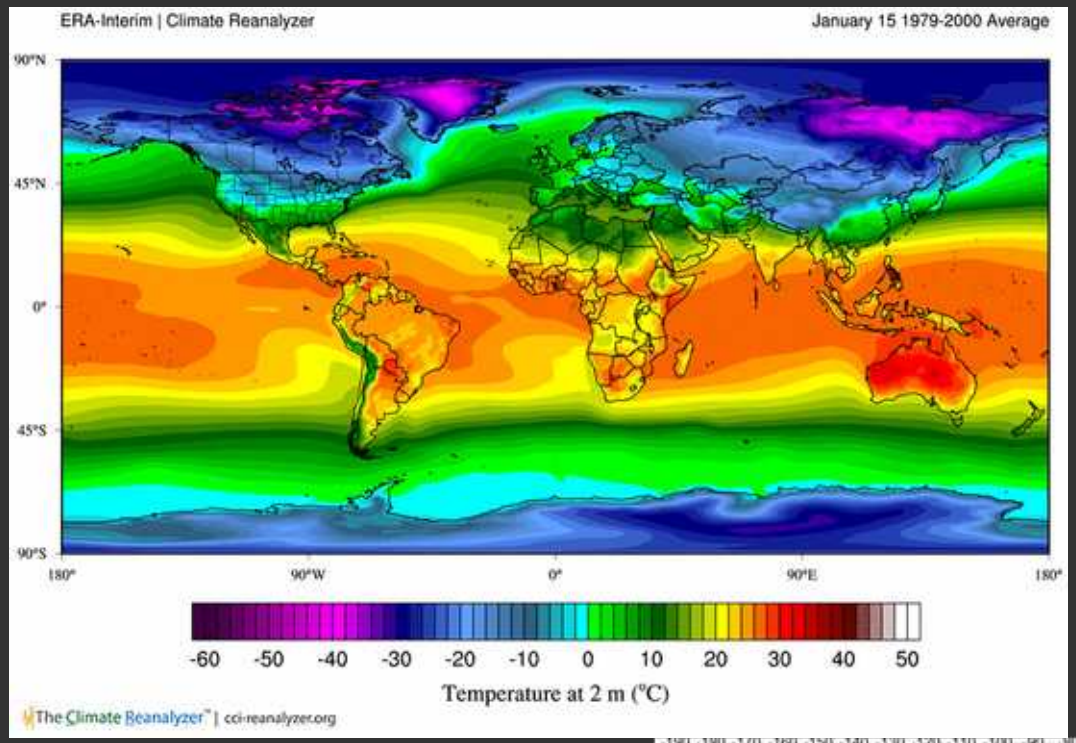
# Climate plays huge role in ecology

Climate is NOT weather!!!



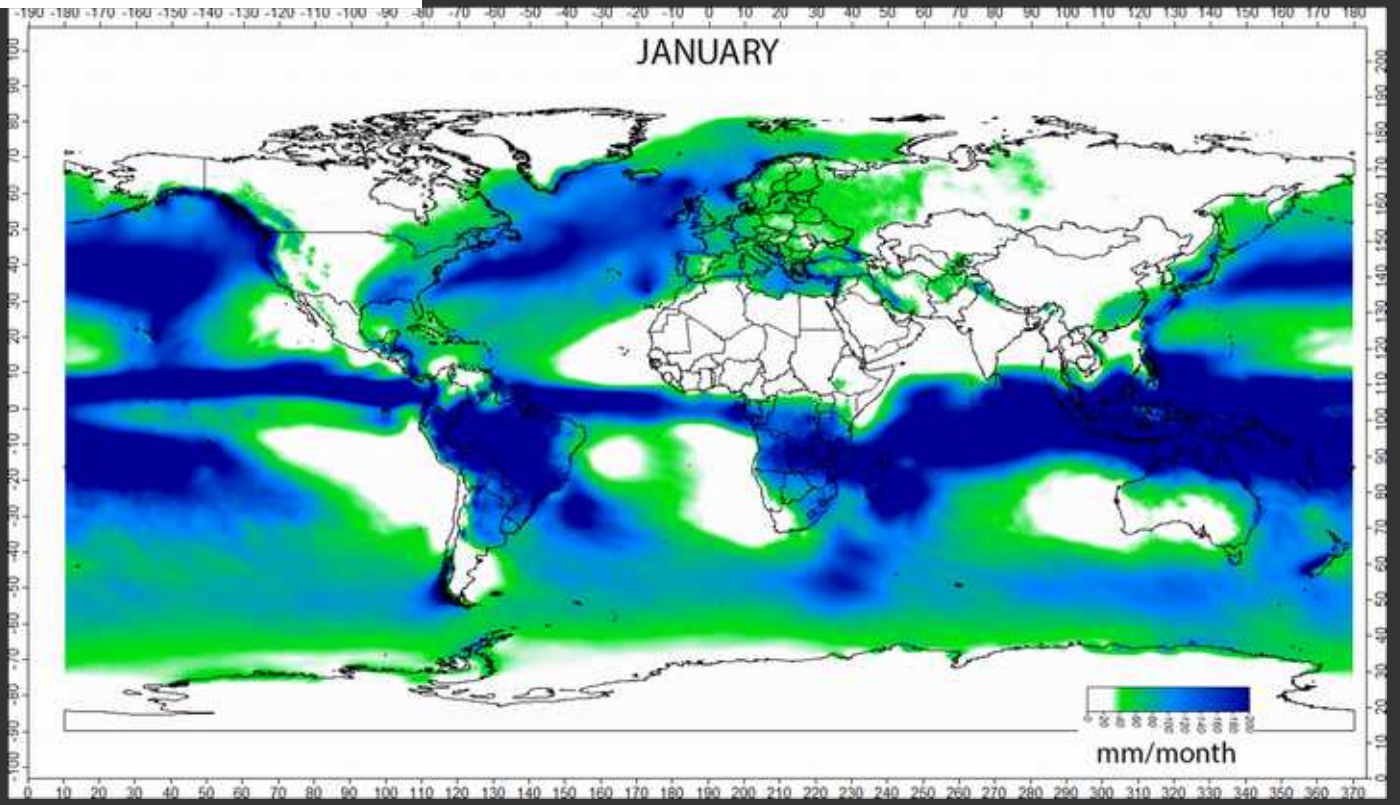



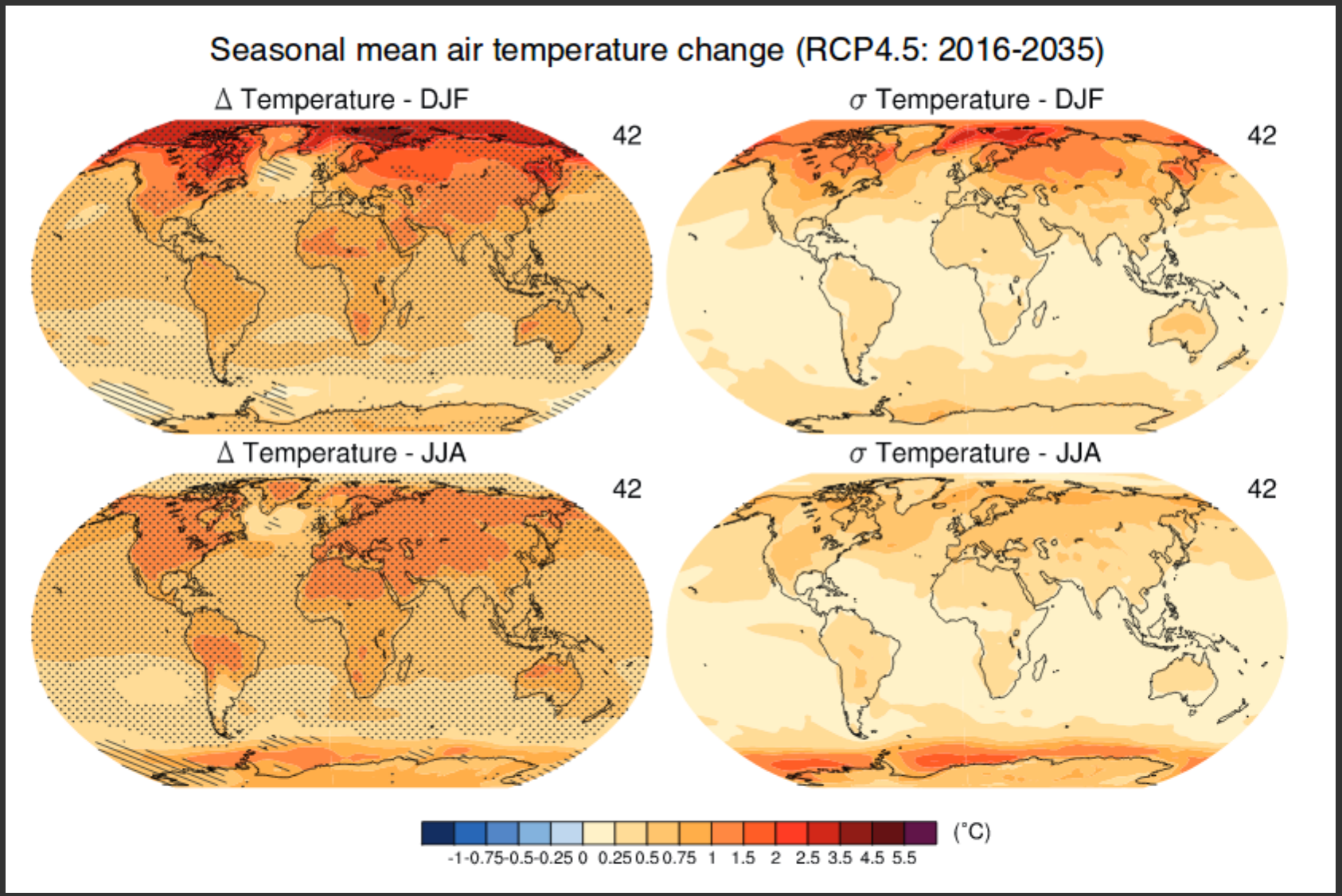

Long-term trends in temperature and precipitation



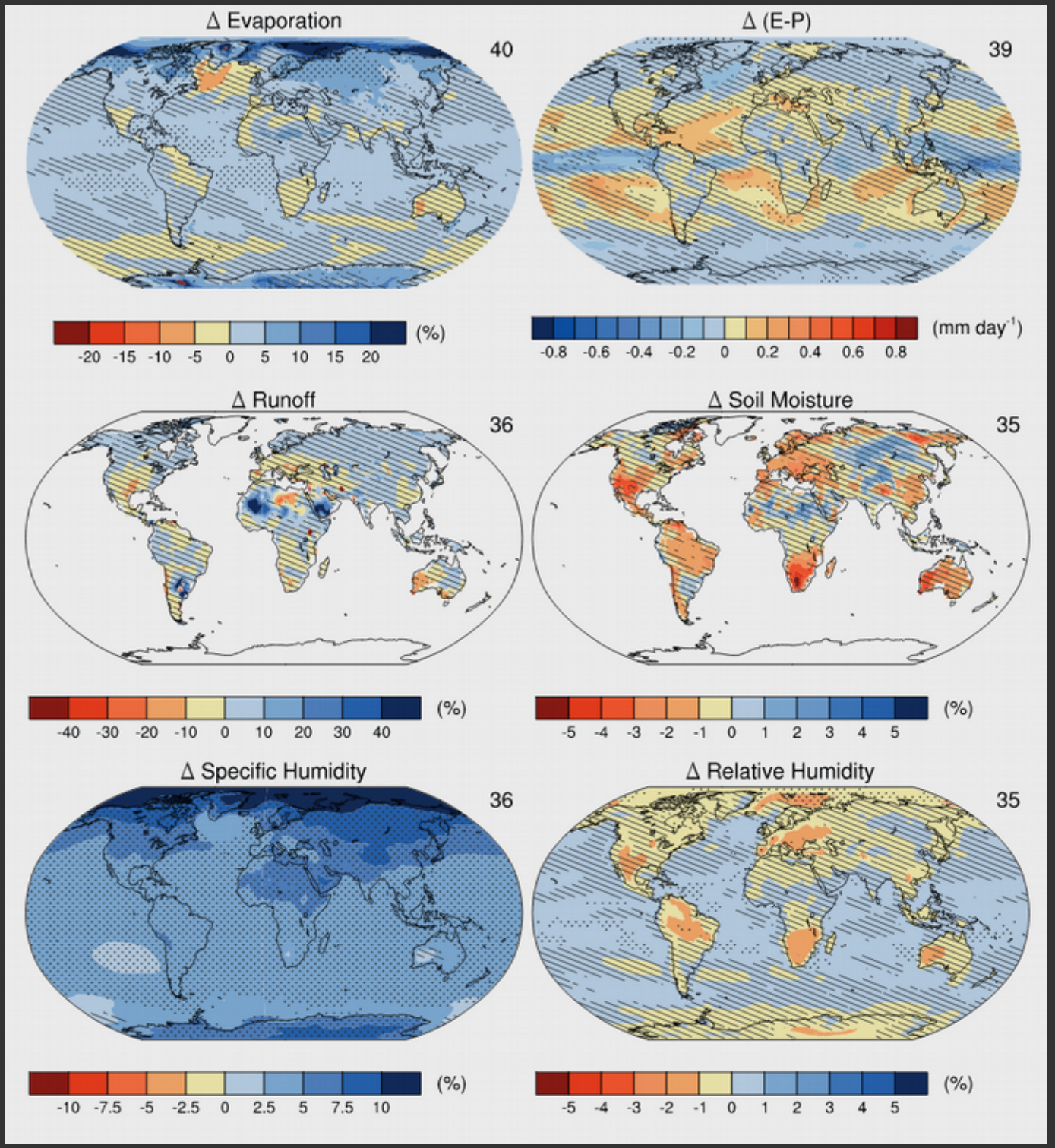

Temperature

Precipitation






Preditions for 2035
95% certainty

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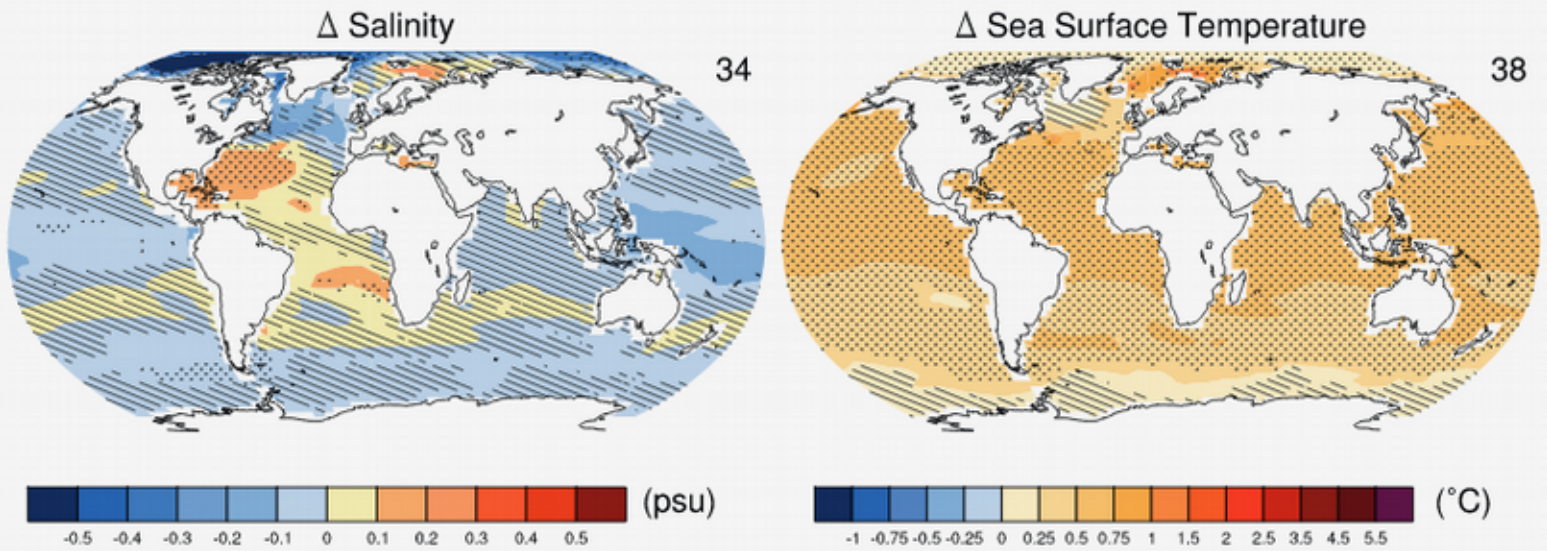
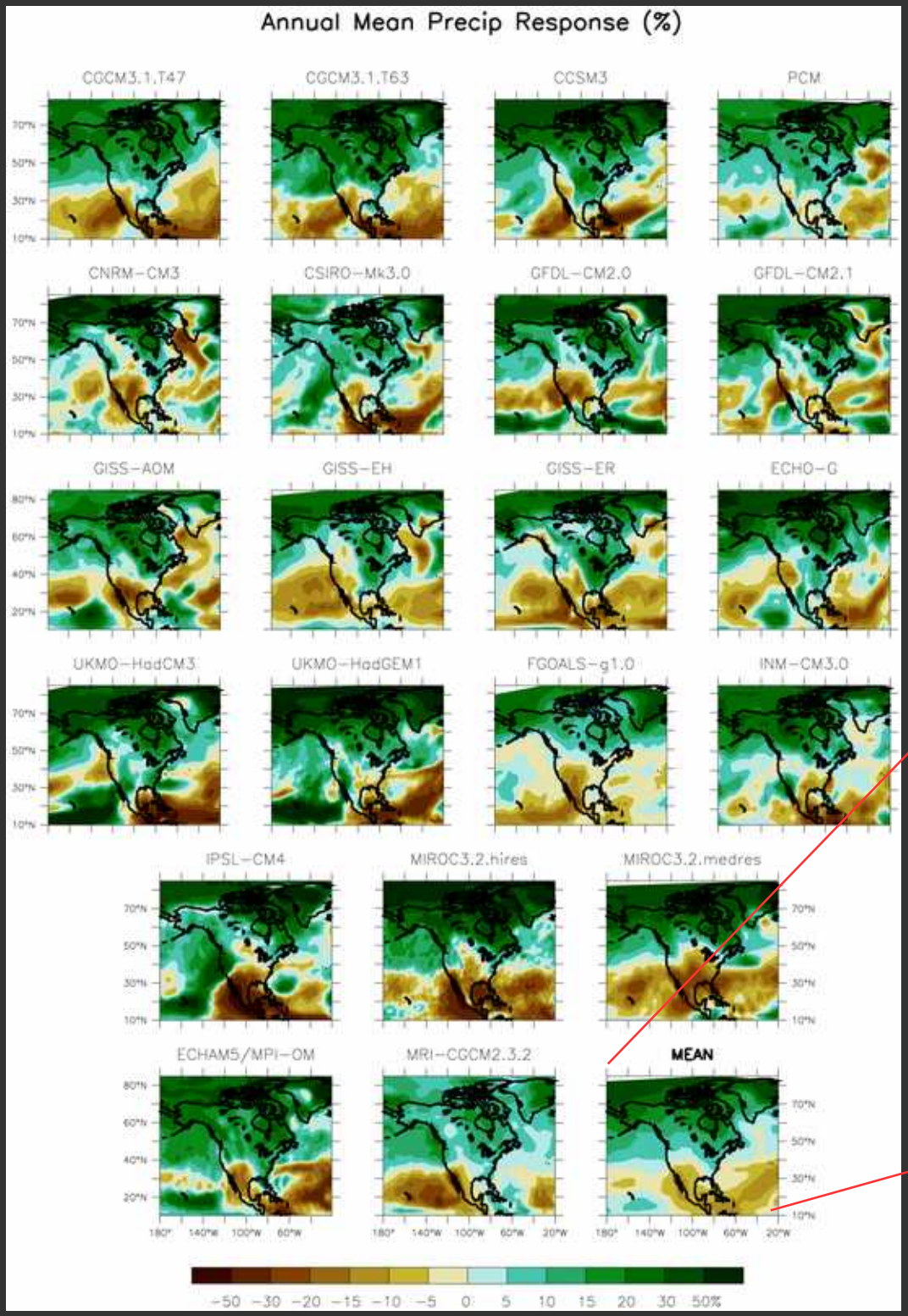
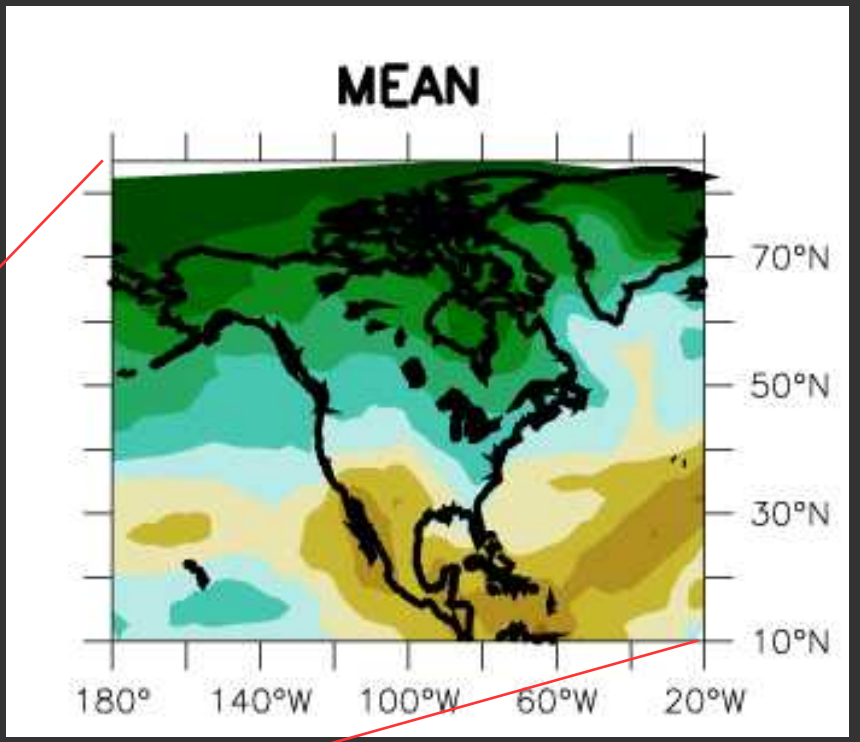



**Figure 11.20 |** CMIP5 multi-model ensemble mean of projected changes in sea surface temperature (right panel; °C) and sea surface salinity (left panel; practical salinity units) for 2016–2035 relative to 1986–2005 under RCP4.5. The number of CMIP5 models used is indicated in the upper right corner.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

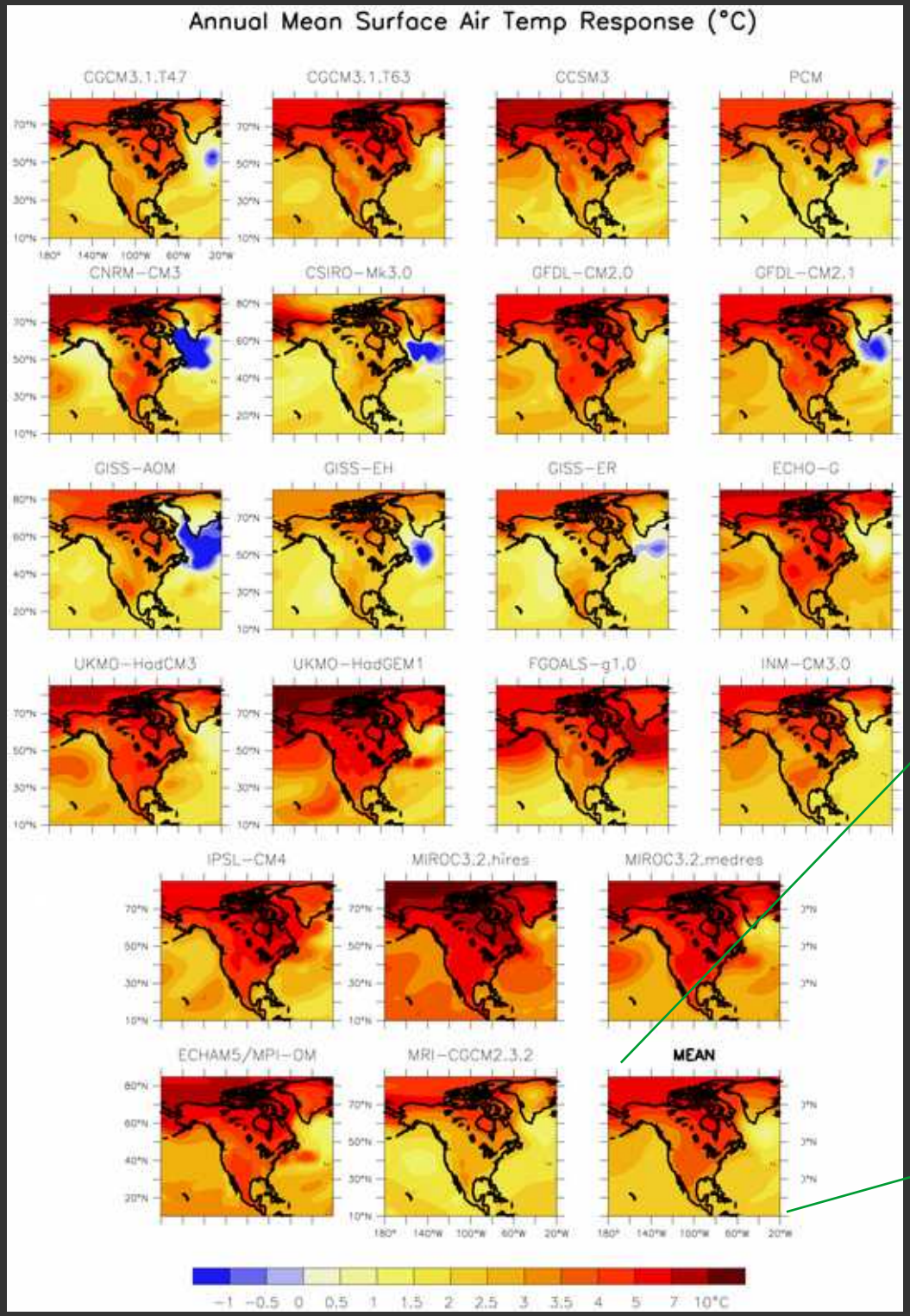



20 independent research groups around the world came up with their own models from the data.

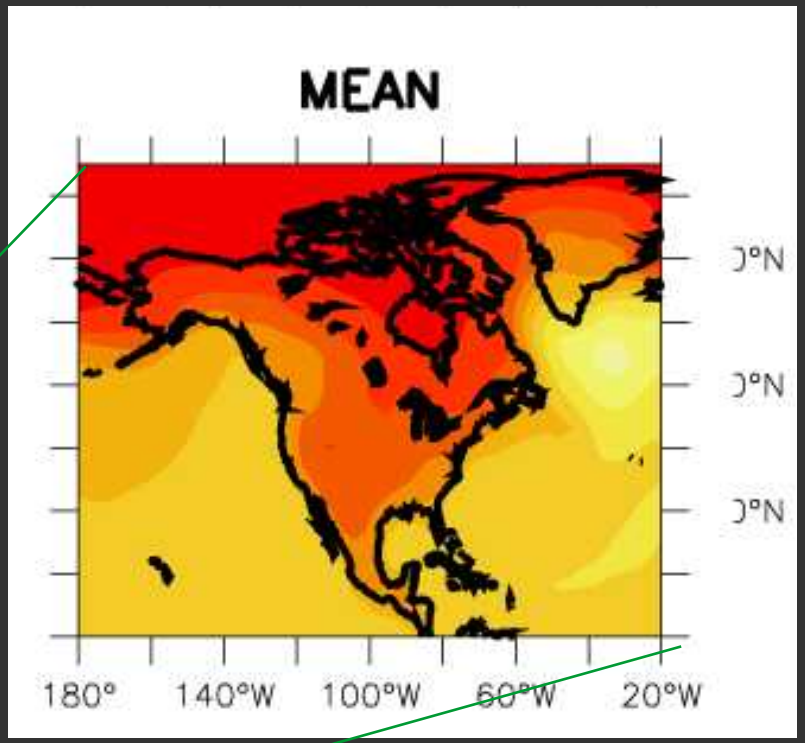
The IPCC figure on the left compiles their separate predictions for 2035.




The average of all the model predictions




Same thing, but temperature



# Snowpack (albedo)

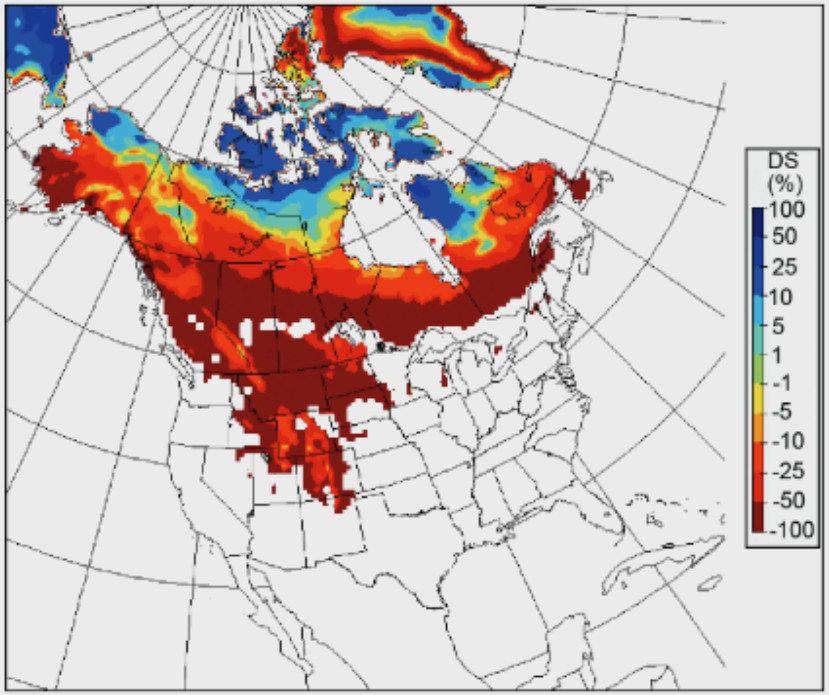



**Figure 11.13.** *Percent snow depth changes in March (only calculated where climatological snow amounts exceed 5 mm of water equivalent), as projected by the Canadian Regional Climate Model (CRCM; Plummer et al., 2006), driven by the Canadian General Circulation Model (CGCM), for 2041 to 2070 under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

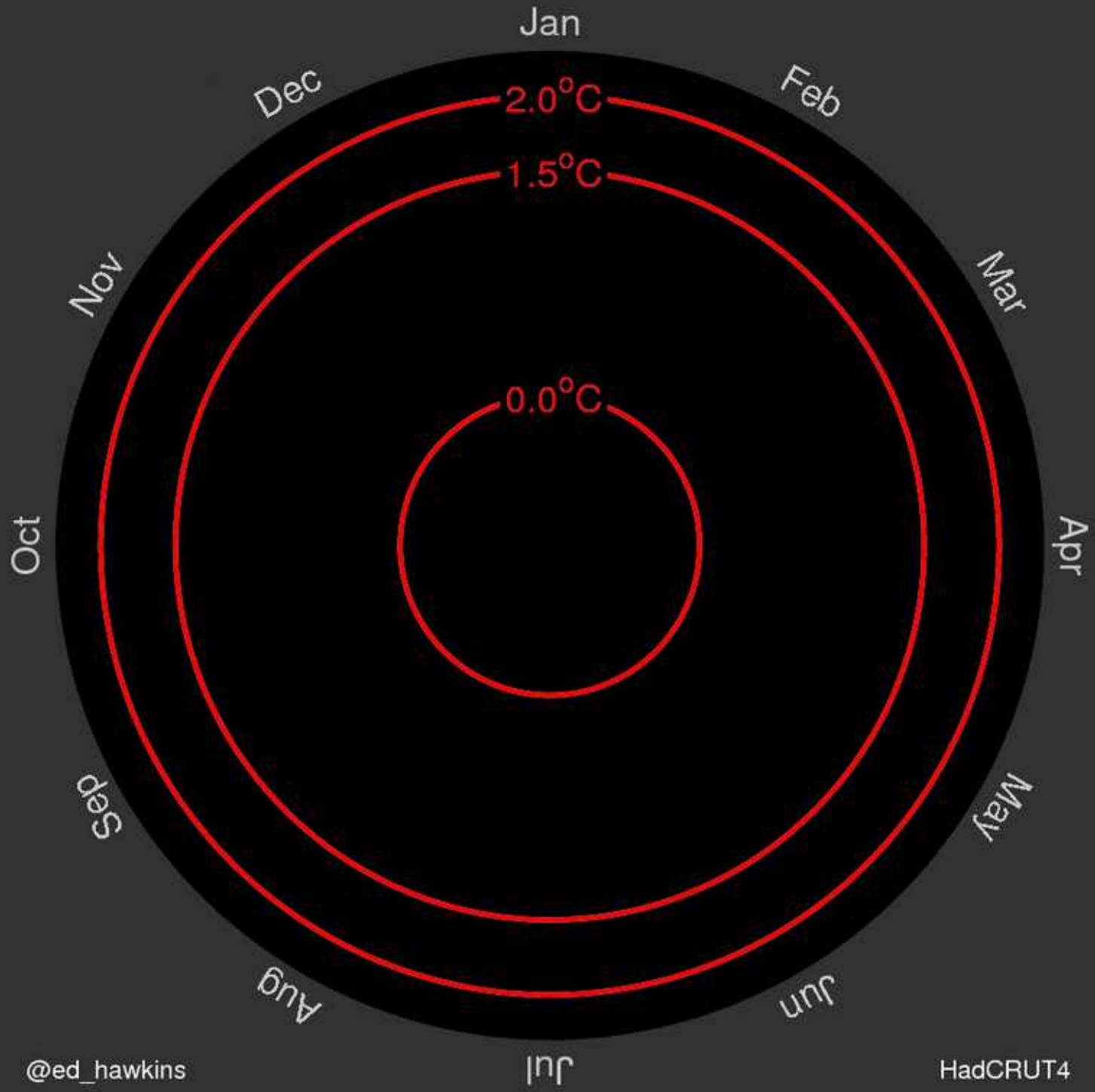
Given current trends in human activity (unchanged), Utah snowpack in 2041 is projected to be around 30% of what it currently averages

These models have 80% accuracy

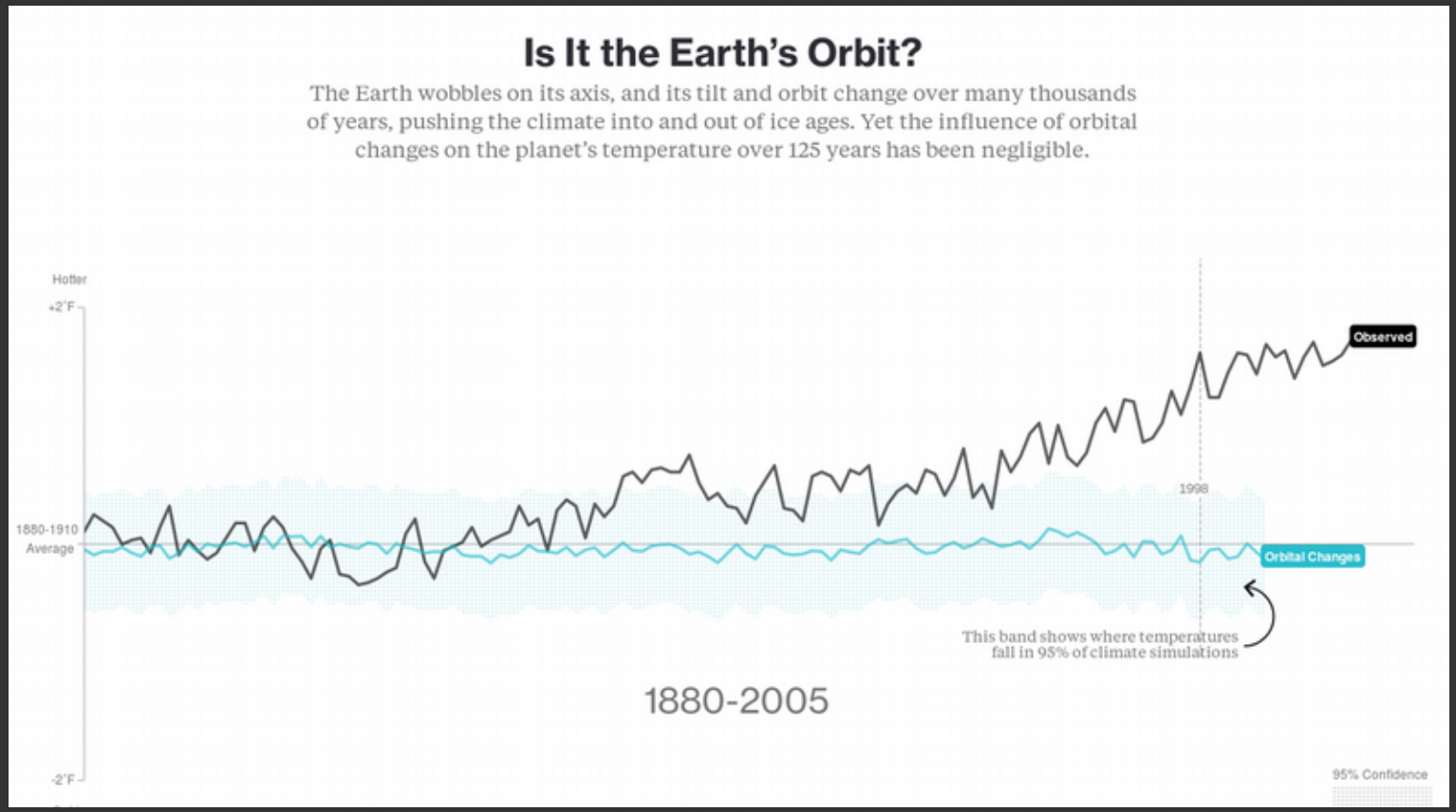
So, conservatively, we can say that if something doesn't change, Wasatch/Unita will have half their current snow within ~50 years

Orem = St. George?

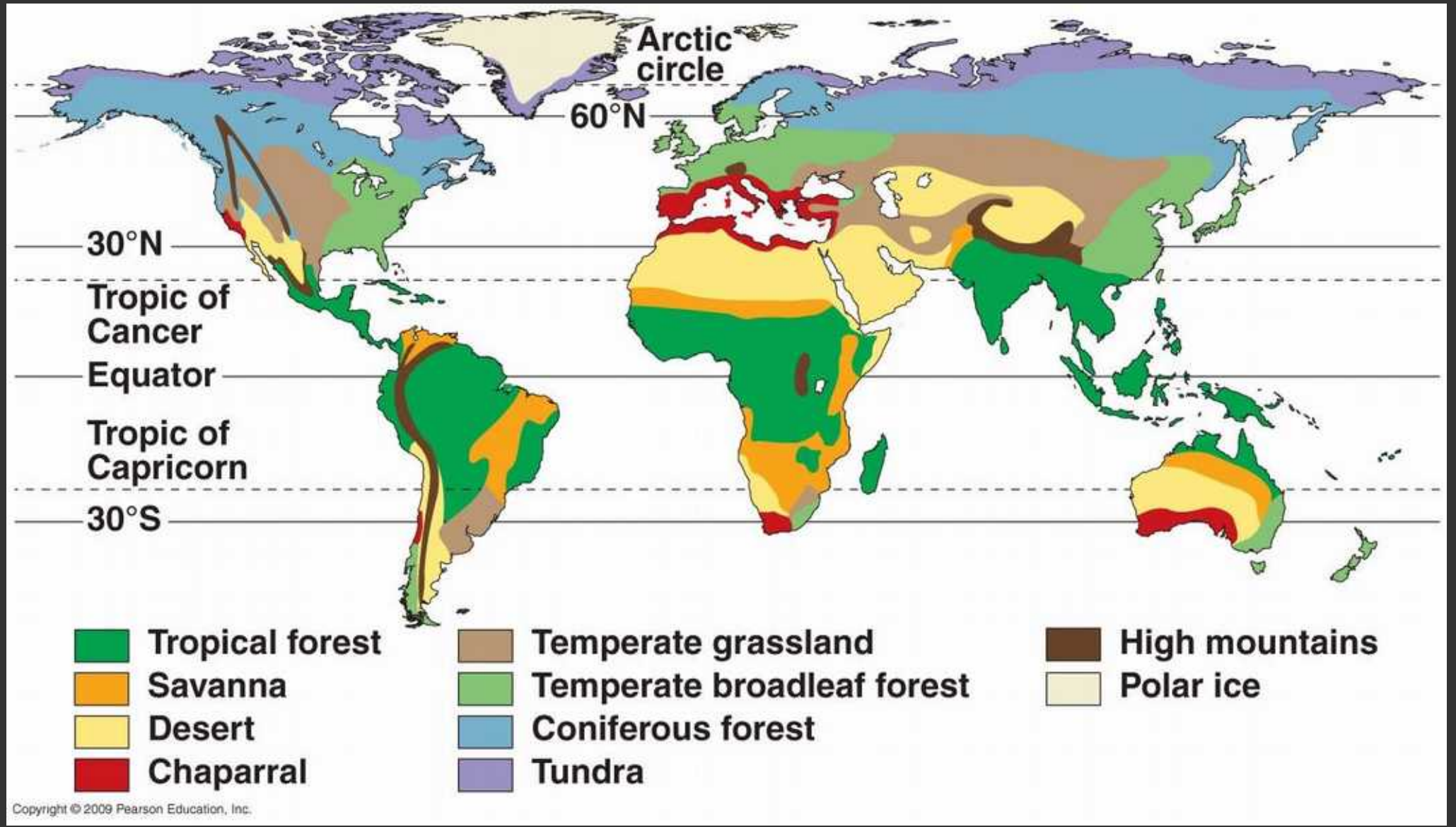
# Global temperature change (1850–2016)



https://www.bloomberg.com/graphics/2015-whats-warming-the-world/



# Due to temperature and precipitation (mostly)



# Tropical Forest

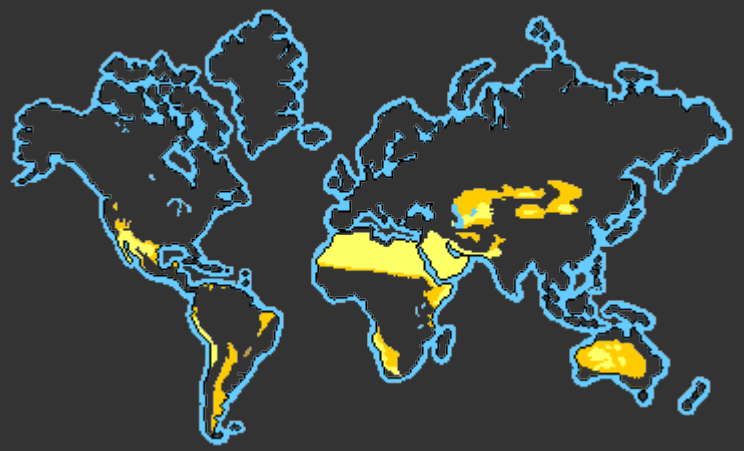
Warm and wet

# Savanna (tropical grassland)

Warm and not wet enough for forest

# Desert

Hot/Cold and Dry



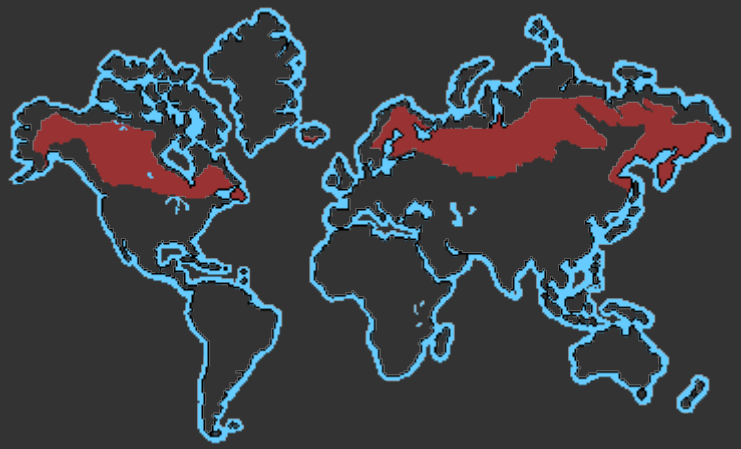
# Chaparral

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

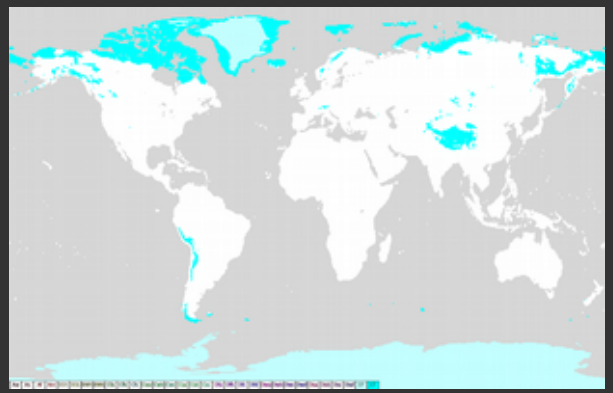
Dry and cold
Low-nutrient
No trees

# High Mountains (Apline)

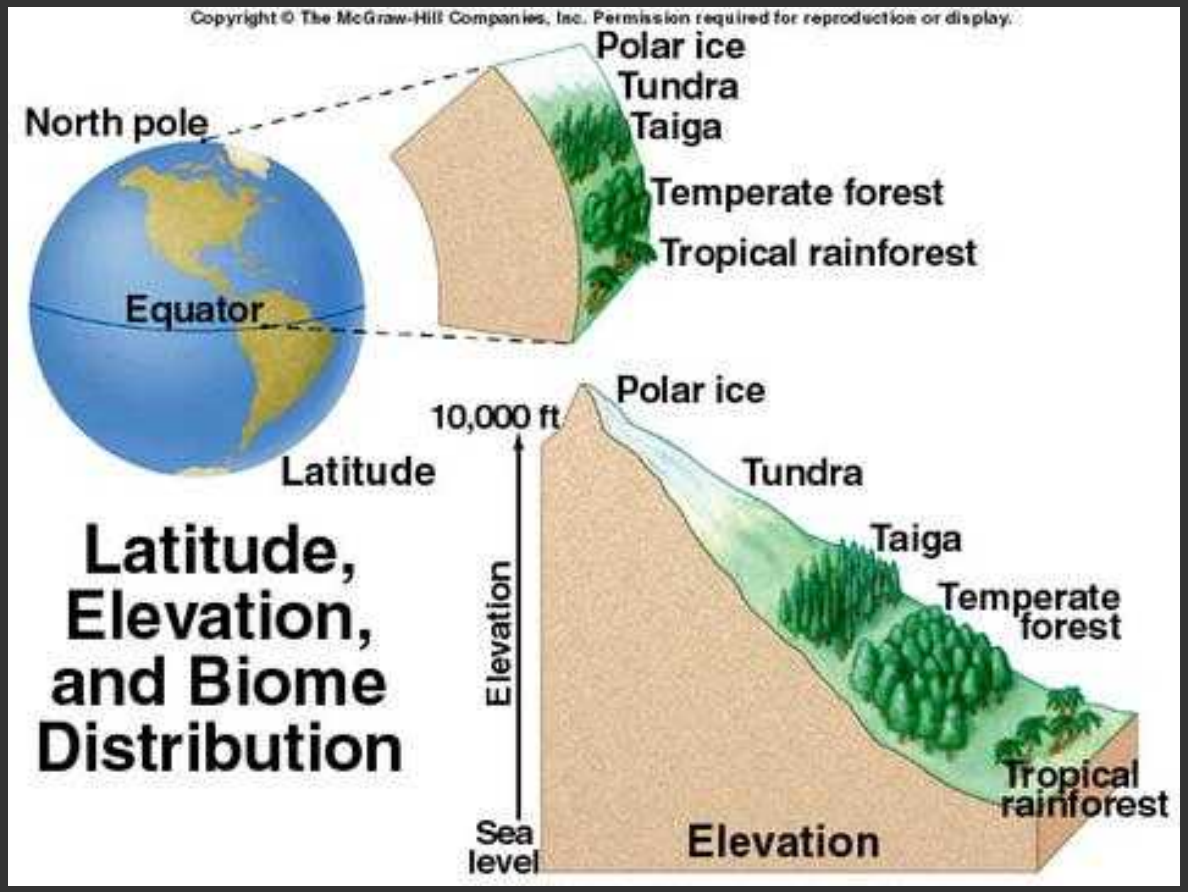
Cold
High-elevation
High-UV
Low diversity

# Polar Ice

Frozen and very dry
No plants

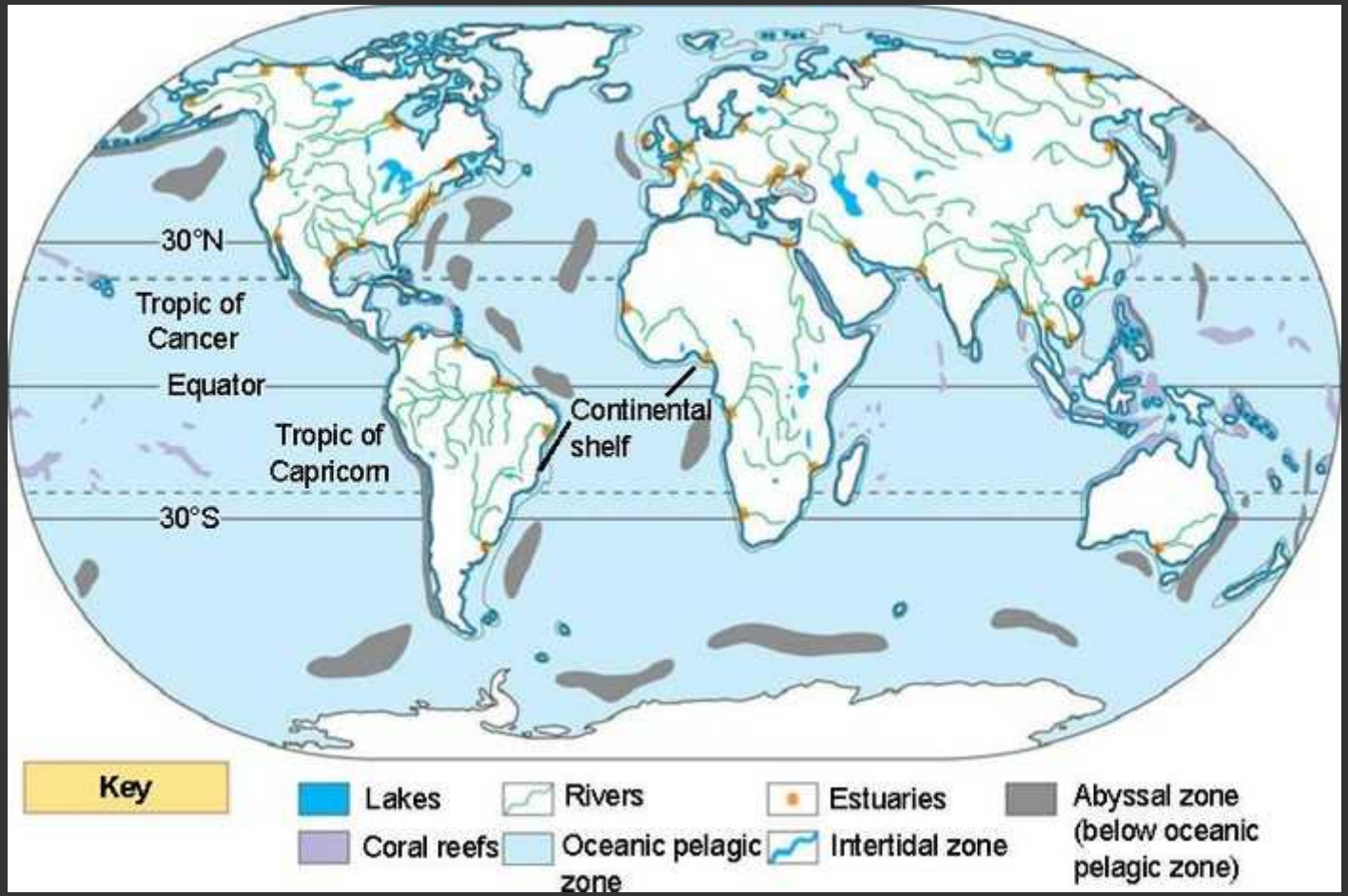


# Location, Location, Location

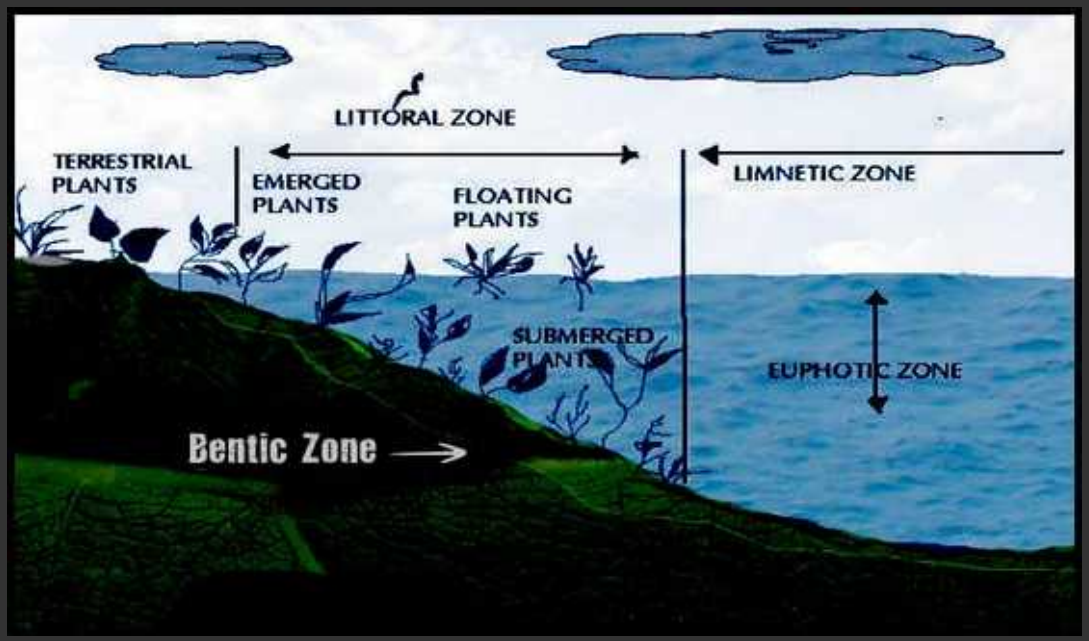


# How do you turn one biome into another?

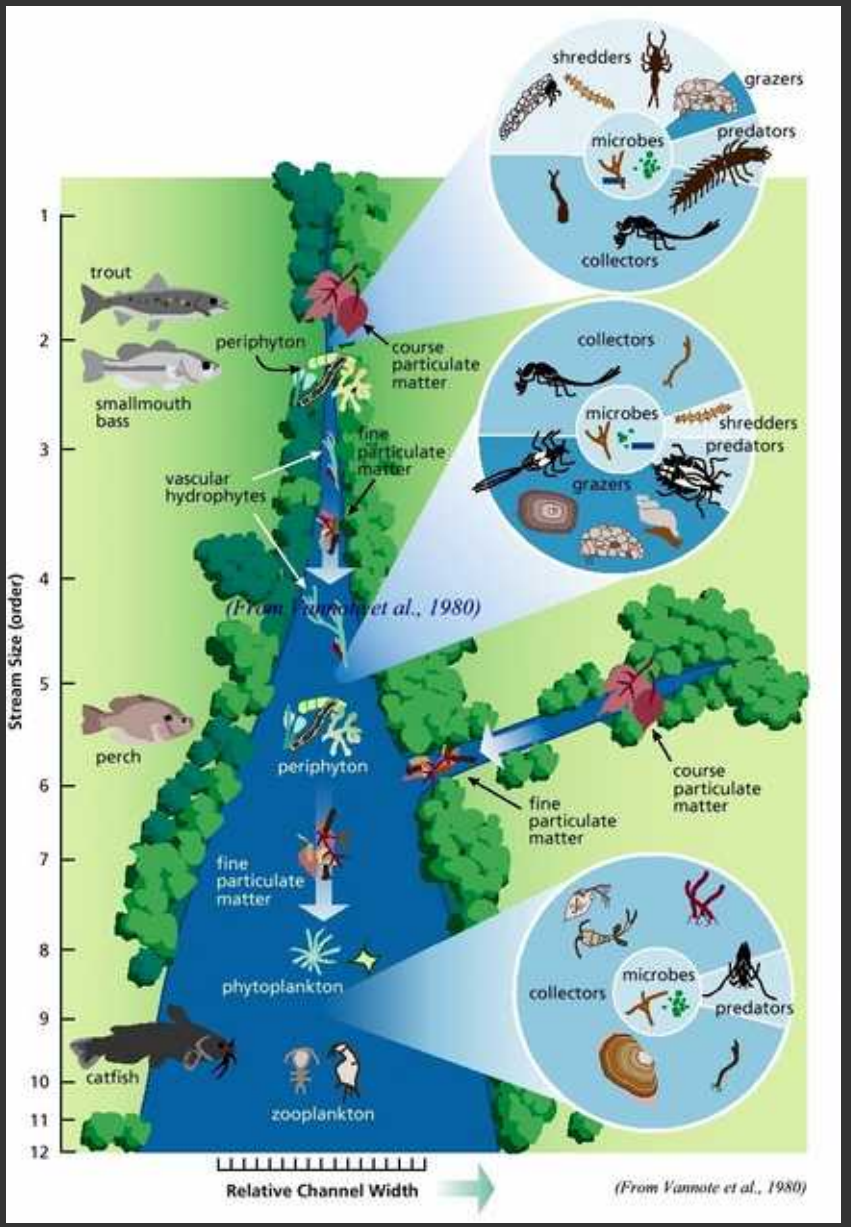
# Aquatic Biomes



# Lake

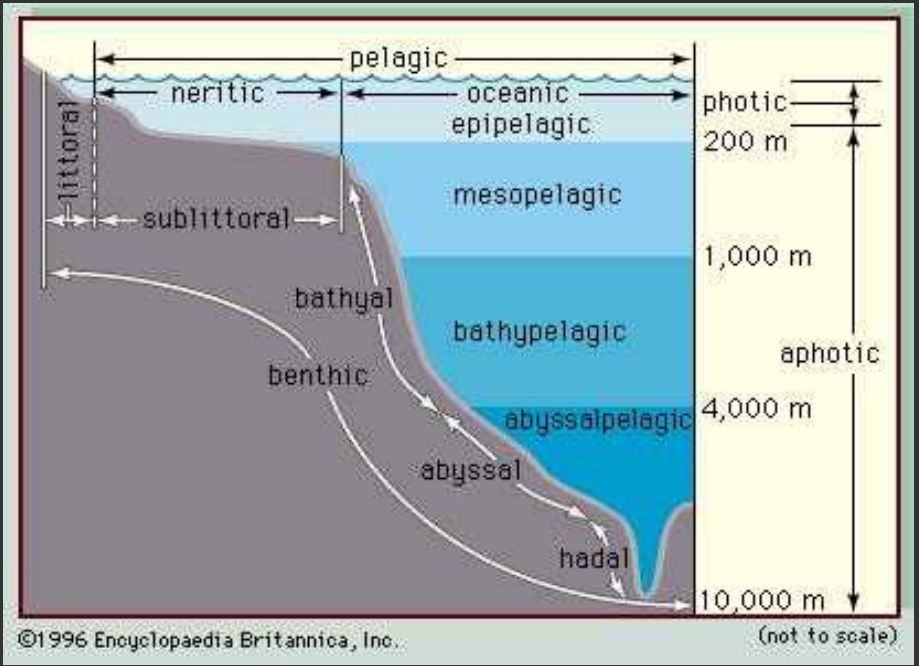

LITTORAL ZONE
TERRESTRIAL PLANTS
EMERGED PLANTS
FLOATING PLANTS
LIMNETIC ZONE
SUBMERGED PLANTS
EUPHOTIC ZONE
Bentic Zone

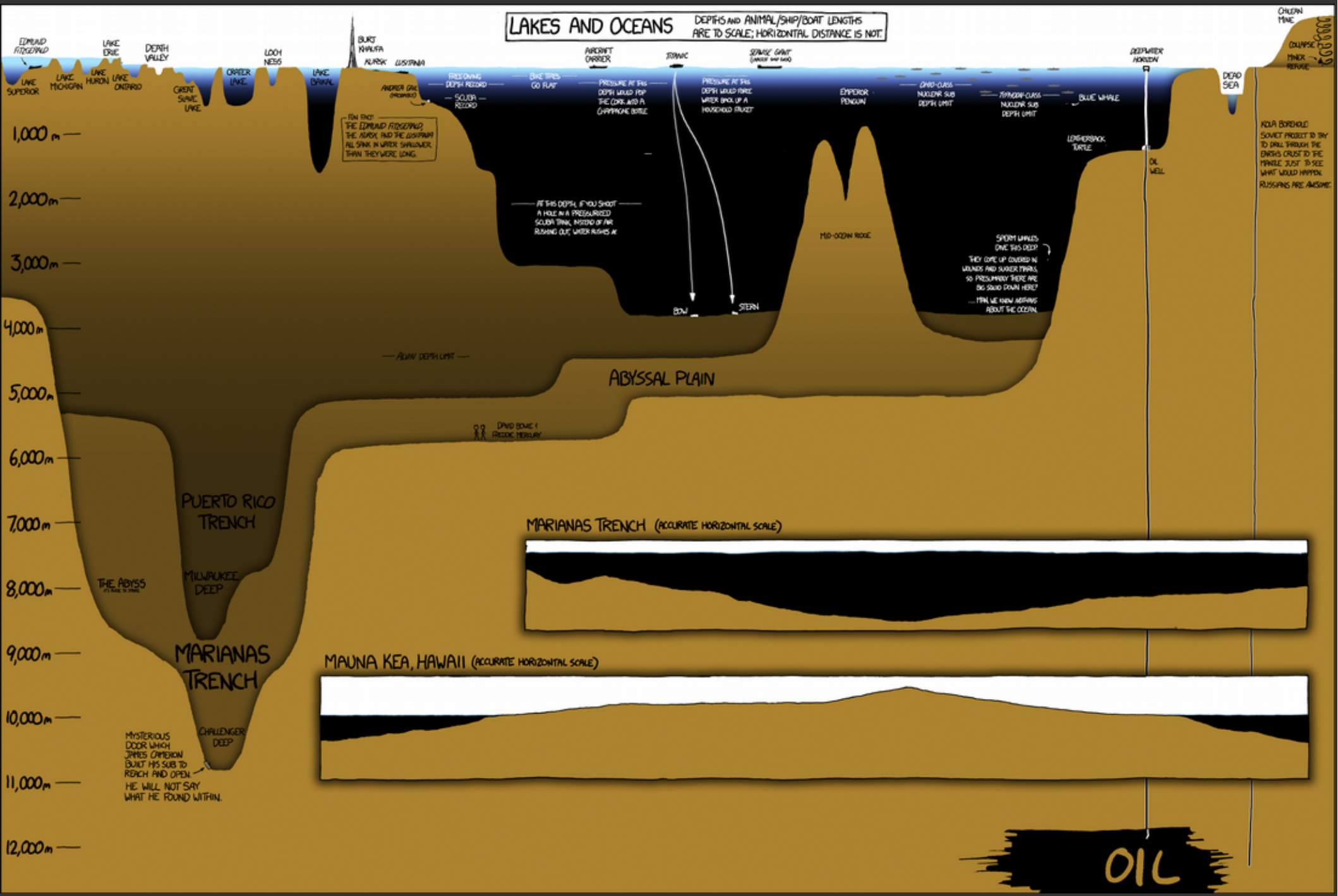
# River


shredders
grazers
microbes
predators
collectors
trout
periphyton
course particulate matter
smallmouth bass
fine particulate matter
vascular hydrophytes
(From Vannote et al., 1980)
Stream Size (order)
perch
periphyton
fine particulate matter
course particulate matter
fine particulate matter
phytoplankton
catfish
zooplankton
Relative Channel Width
(From Vannote et al., 1980)

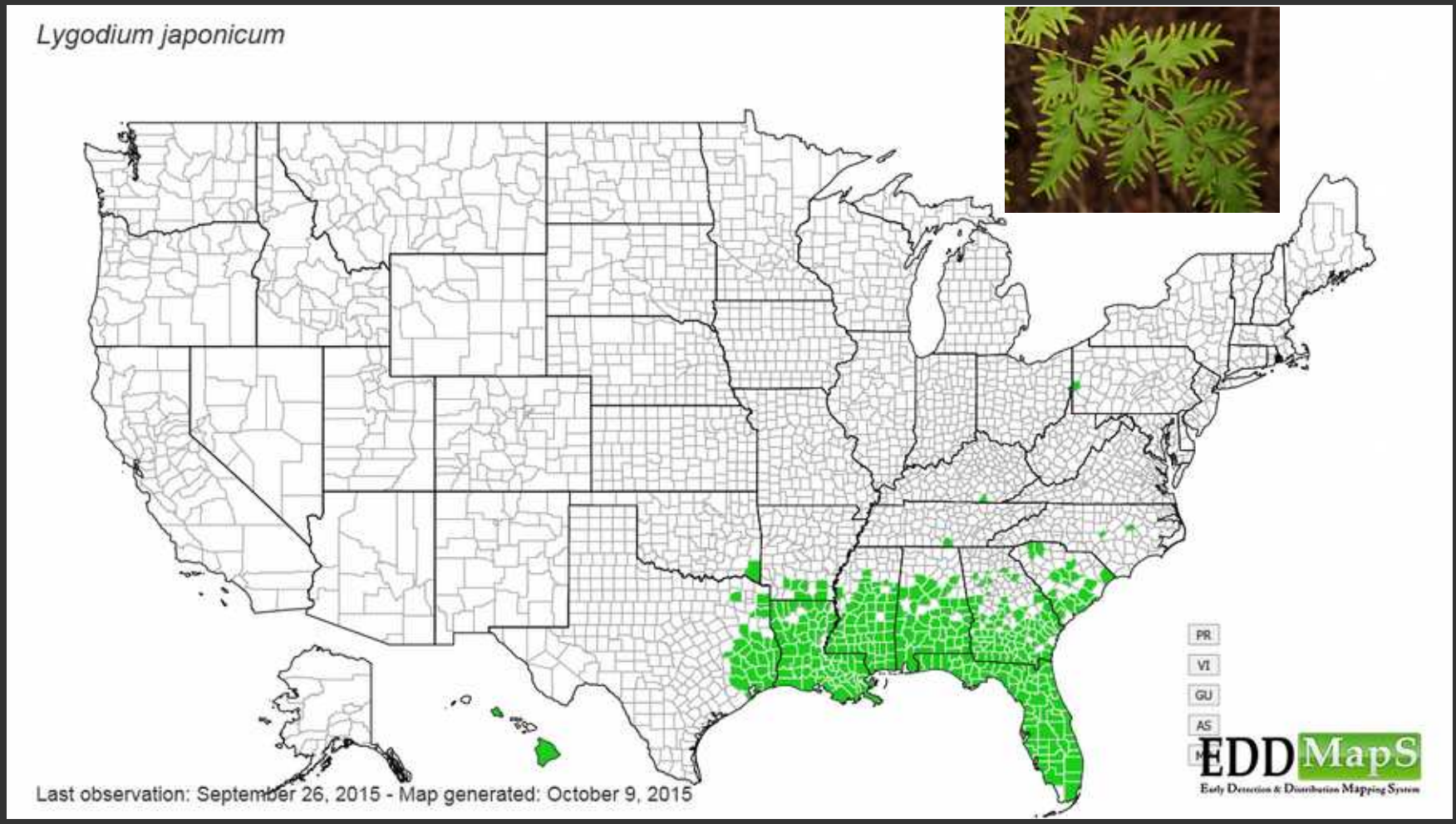
# Coral Reef

# Marine Pelagic



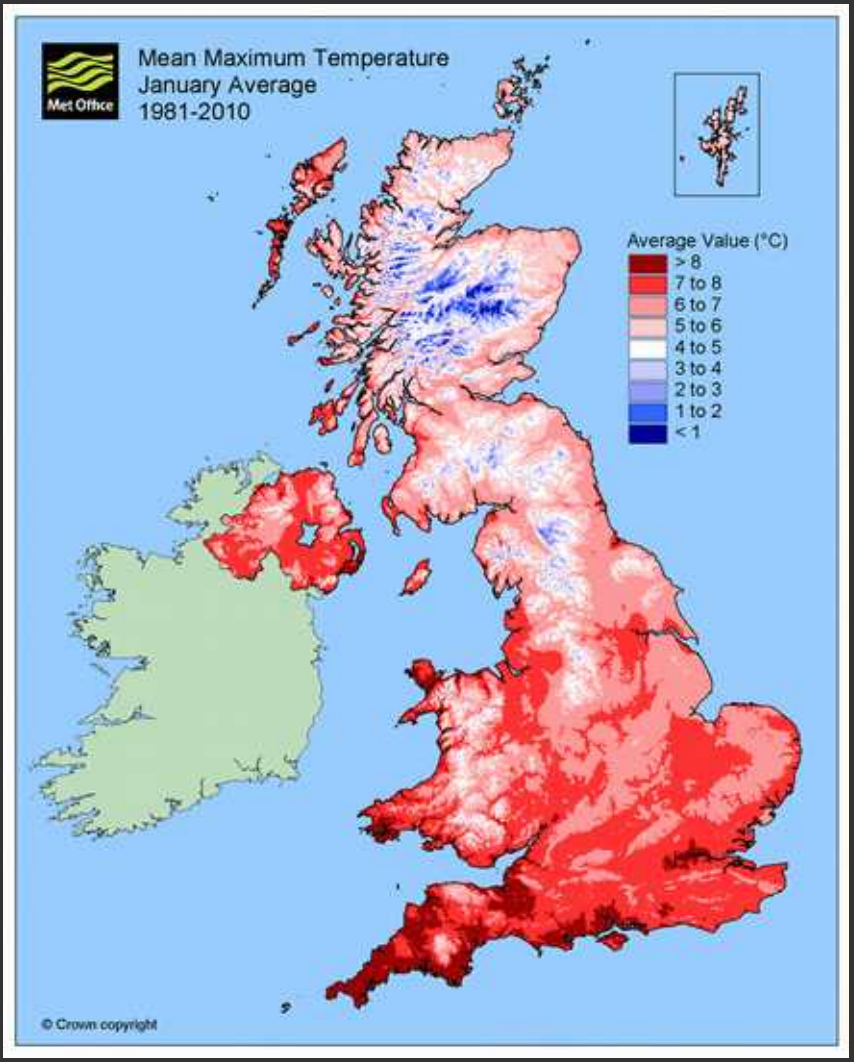


LAKES AND OCEANS
DEPTHS AND ANIMAL/SHIP/BOAT LENGTHS ARE TO SCALE; HORIZONTAL DISTANCE IS NOT.
EDMUND FITZGERALD
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
DEATH VALLEY
GREAT SALT LAKE
CRATER LAKE
LOCH NESS
LAKE BAIKAL
BURJ KHALIFA
KURSK
LUSITANIA
ANDREA DORIA (PROBABLE)
FUN FACT! THE EDMUND FITZGERALD, THE KURSK, AND THE LUSITANIA ALL SANK IN WATER SHALLOWER THAN THEY WERE LONG.
FREE DIVING DEPTH RECORD
SCUBA RECORD
BIKE TIRES GO FLAT
AT THIS DEPTH, IF YOU SHOOT A HOLE IN A PRESSURIZED SCUBA TANK, INSTEAD OF AIR RUSHING OUT, WATER RUSHES IN
AIRCRAFT CARRIER
PRESSURE AT THIS DEPTH WOULD POP THE CORK AND A CHAMPAGNE BOTTLE
TITANIC
SEAWISE GIANT (LARGEST SHIP EVER)
PRESSURE AT THIS DEPTH WOULD FORCE WATER BACK UP A HOUSEHOLD FAUCET
BOW
STERN
EMPEROR PENGUIN
OHIO-CLASS NUCLEAR SUB DEPTH LIMIT
TYPHOON-CLASS NUCLEAR SUB DEPTH LIMIT
BLUE WHALE
LEATHERBACK TURTLE
DEEPWATER HORIZON
OIL WELL
DEAD SEA
CHILEAN MINE
COLLAPSE
MINER RESCUE
KOLA BOREHOLE
SOVIET PROJECT TO TRY TO DRILL THROUGH THE EARTH'S CRUST TO THE MANTLE JUST TO SEE WHAT WOULD HAPPEN.
RUSSIANS ARE AWESOME.
1,000 m
2,000 m
3,000 m
4,000 m
5,000 m
6,000 m
7,000 m
8,000 m
9,000 m
10,000 m
11,000 m
12,000 m
MID-OCEAN RIDGE
SPERM WHALES DIVE THIS DEEP
THEY COME UP COVERED IN WOUNDS AND SUCKER MARKS, SO PRESUMABLY THERE ARE BIG SQUID DOWN HERE?
...MAN WE KNOW ALMOST NOTHING ABOUT THE OCEAN.
ABOVE DEPTH LIMIT
ABYSSAL PLAIN
DAVID BOWIE ! FREDDIE MERCURY
PUERTO RICO TRENCH
THE ABYSS
MILWAUKEE DEEP
MARIANAS TRENCH
CHALLENGER DEEP
MYSTERIOUS DOOR WHICH JAMES CAMERON BUILT HIS SUB TO REACH AND OPEN
HE WILL NOT SAY WHAT HE FOUND WITHIN.
MARIANAS TRENCH (ACCURATE HORIZONTAL SCALE)
MAUNA KEA, HAWAII (ACCURATE HORIZONTAL SCALE)
OIL

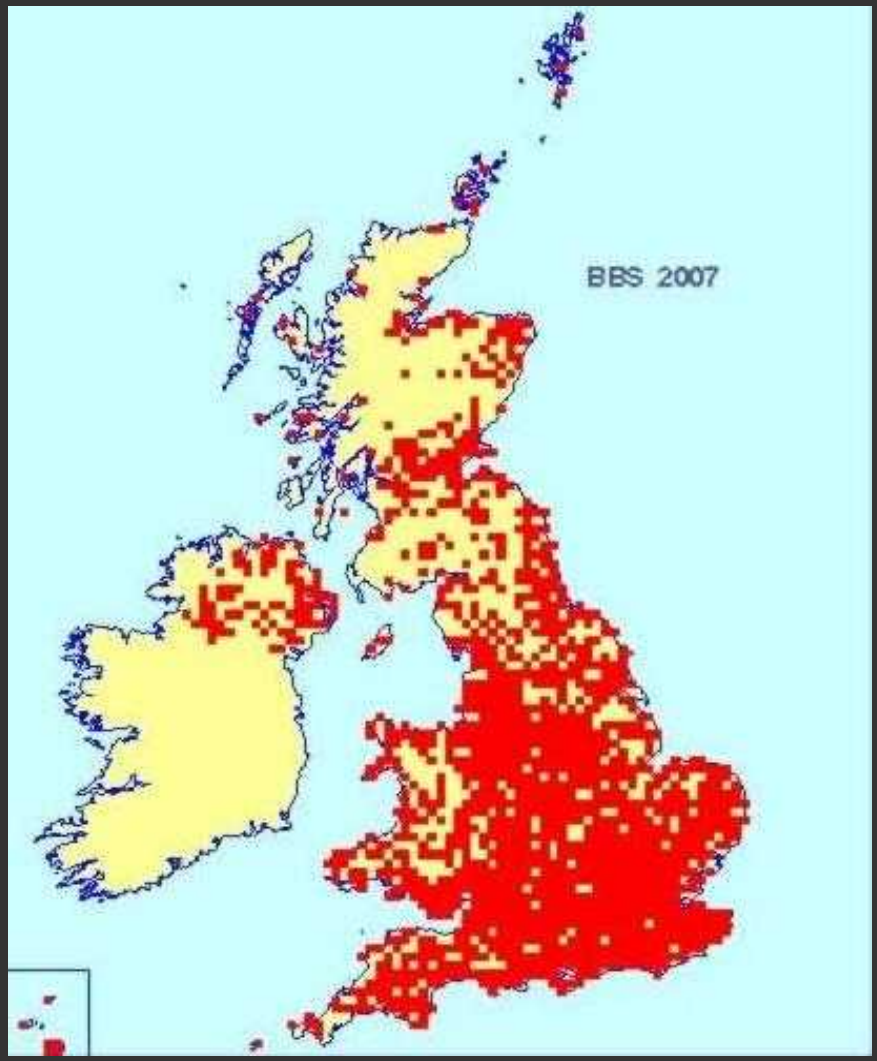
# Dispersal and Distribution




What limits species' distributions?

# Dispersal and Distribution




Skylark distribution in G.B.

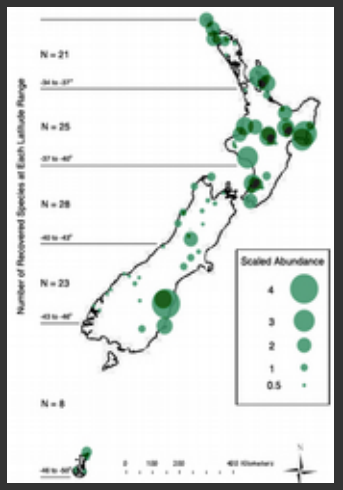
# Factors that influence species' ranges

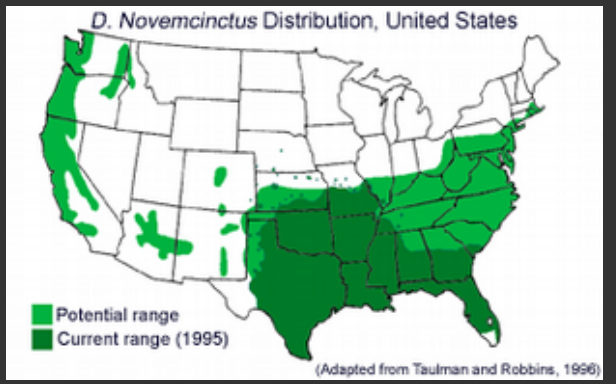
Dispersal adaptations / barriers

Niche availability

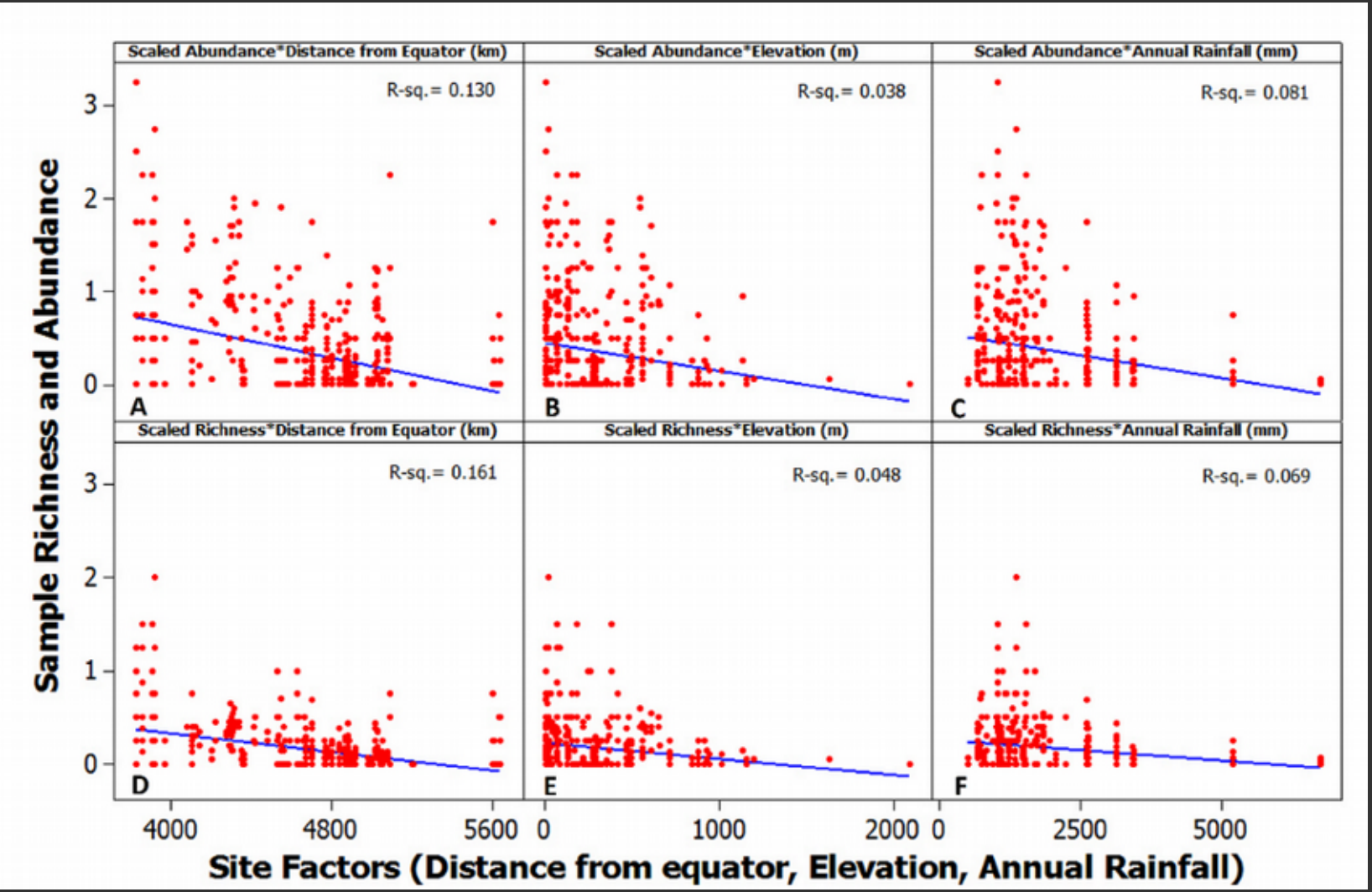
Humans (intentional or not)

Climate

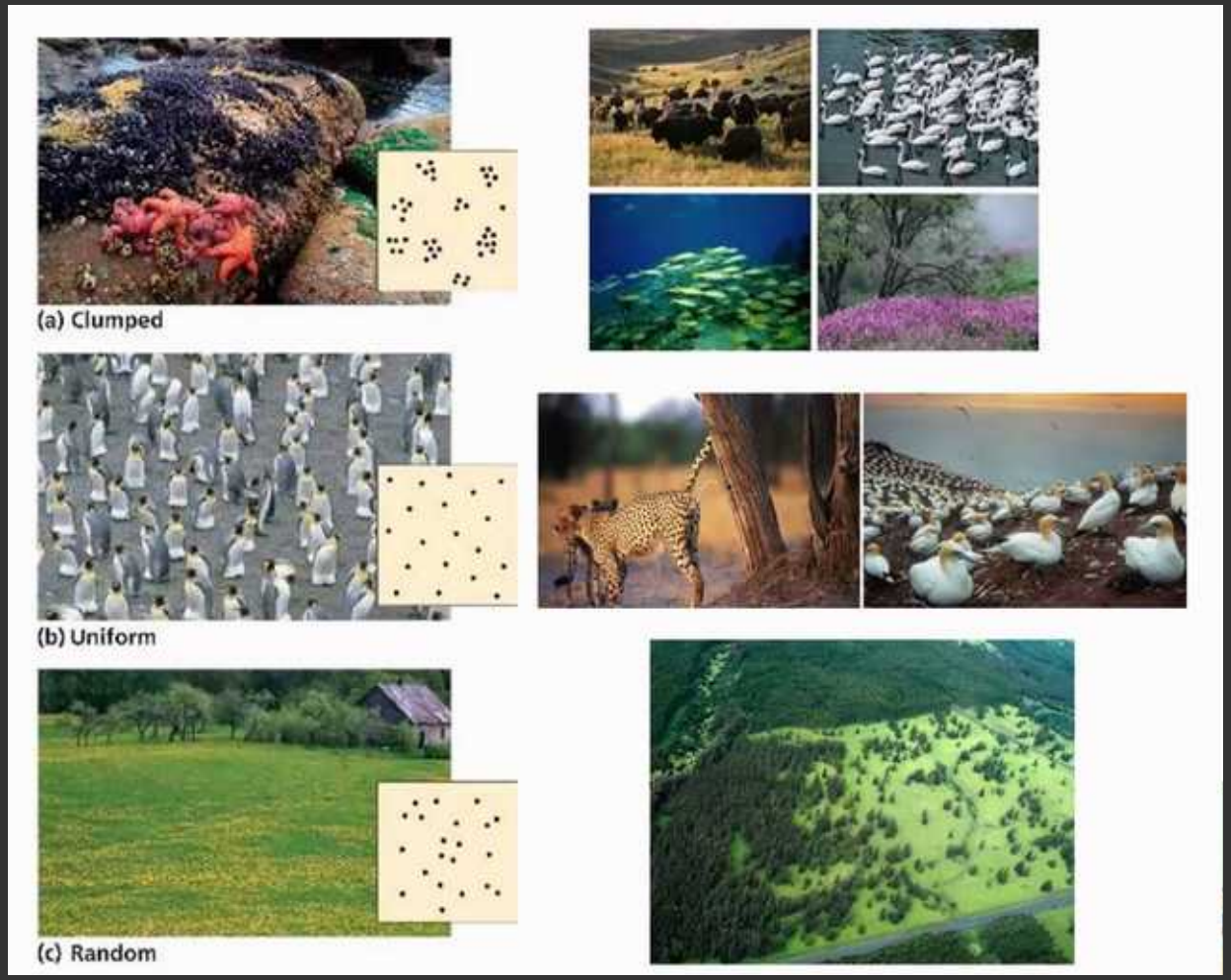


# Location ← → Climate



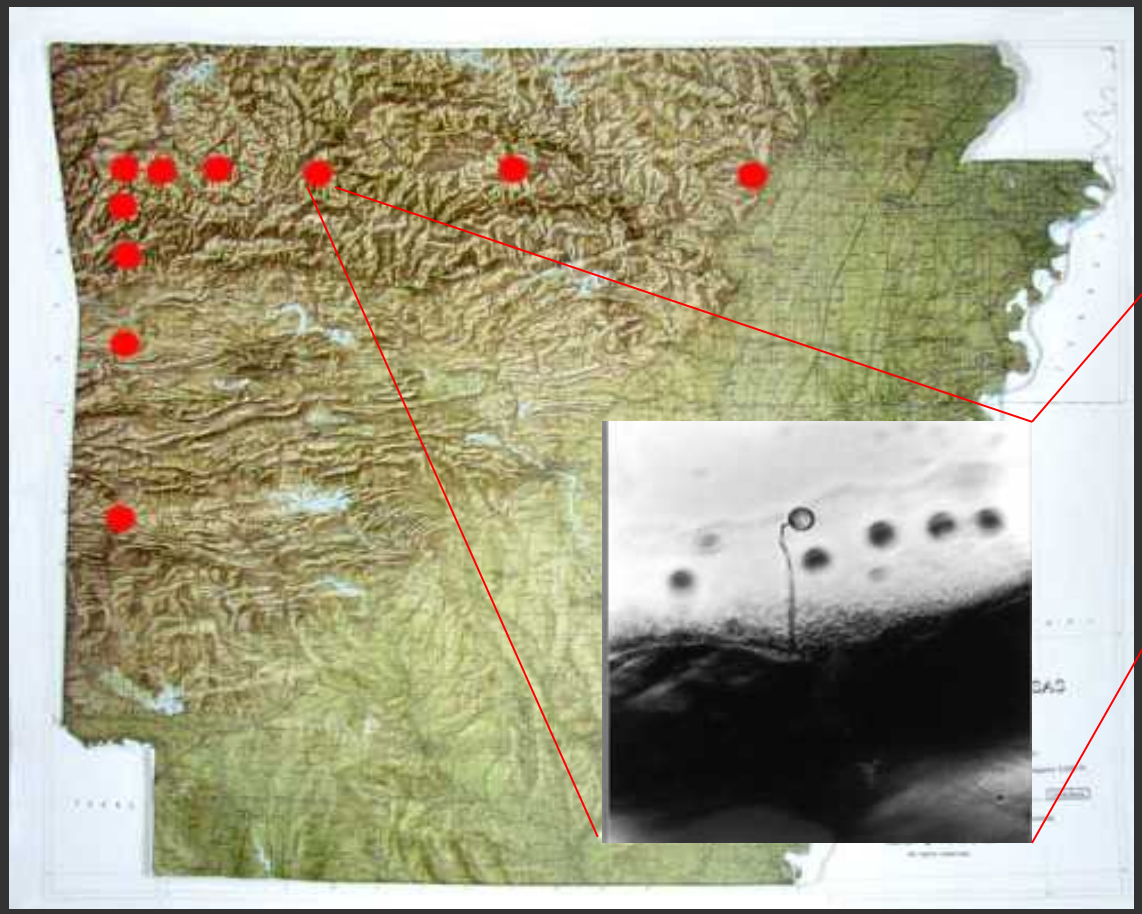
# Population ecology



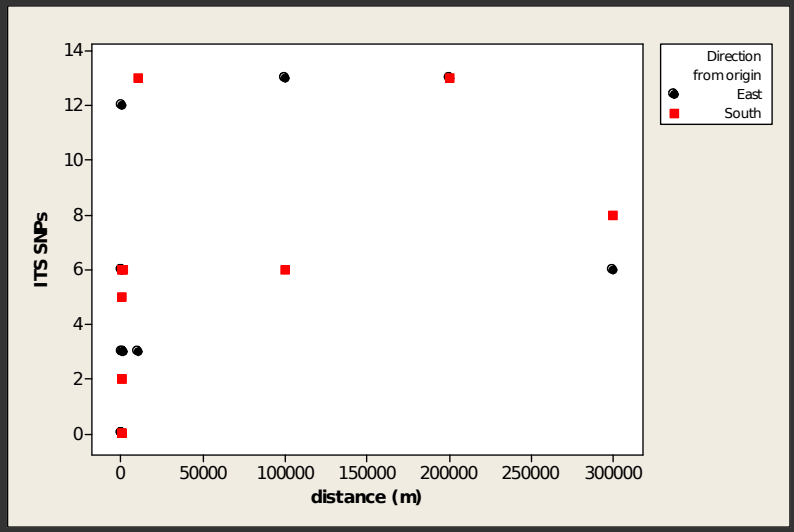

Group of same species in same area

How environment and genetics determines size and structure of populations

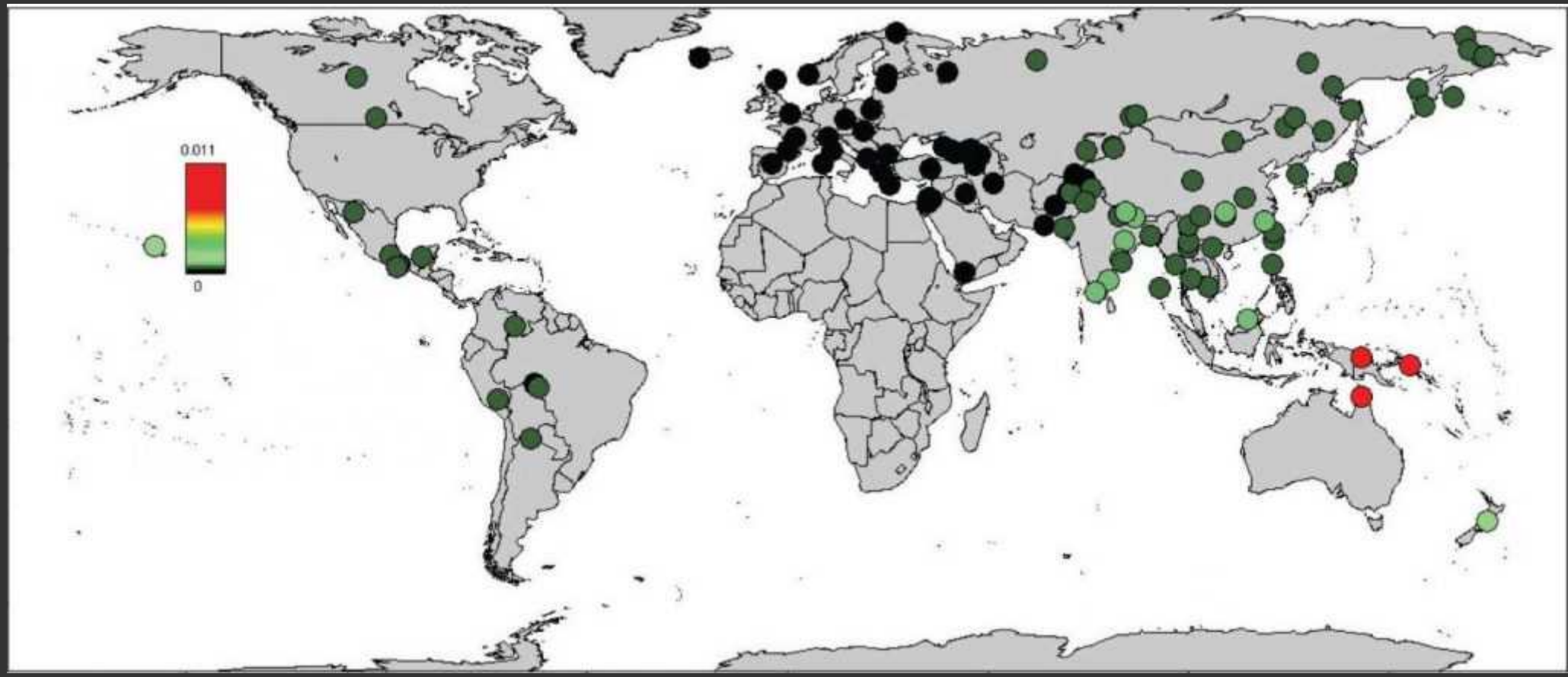
# Population genetics



18S rDNA + ITS1

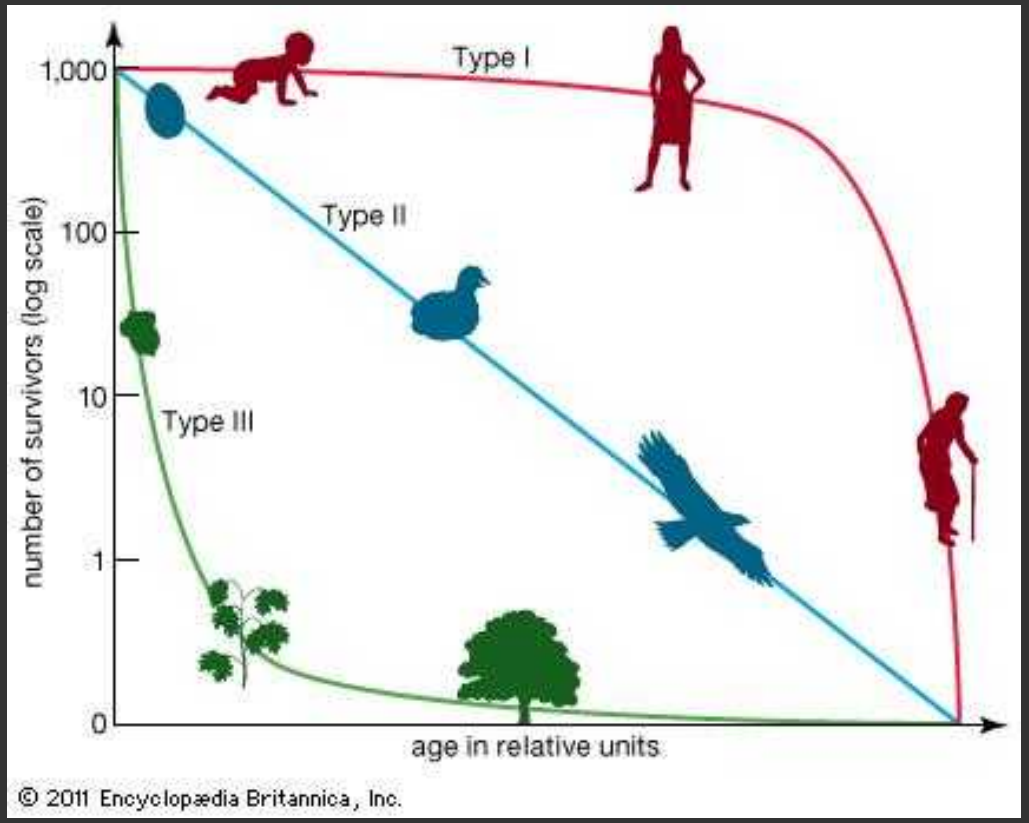


# Tracking specific Neanderthal genes in modern humans

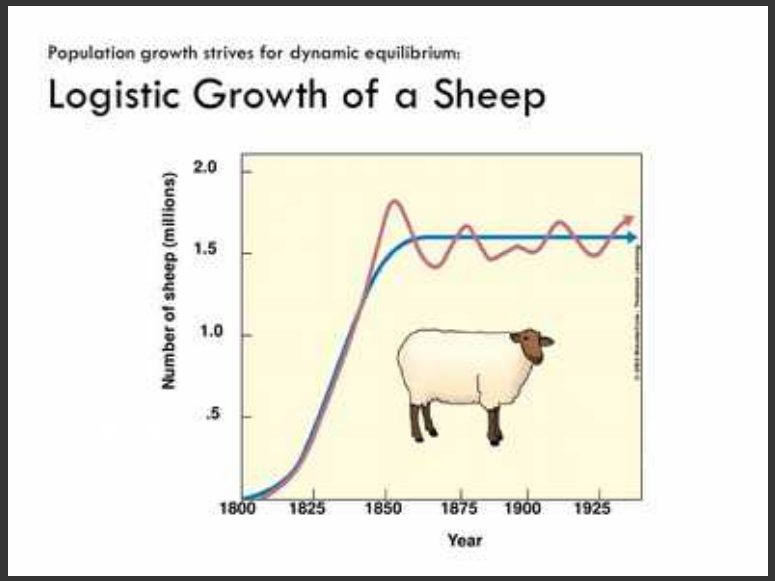


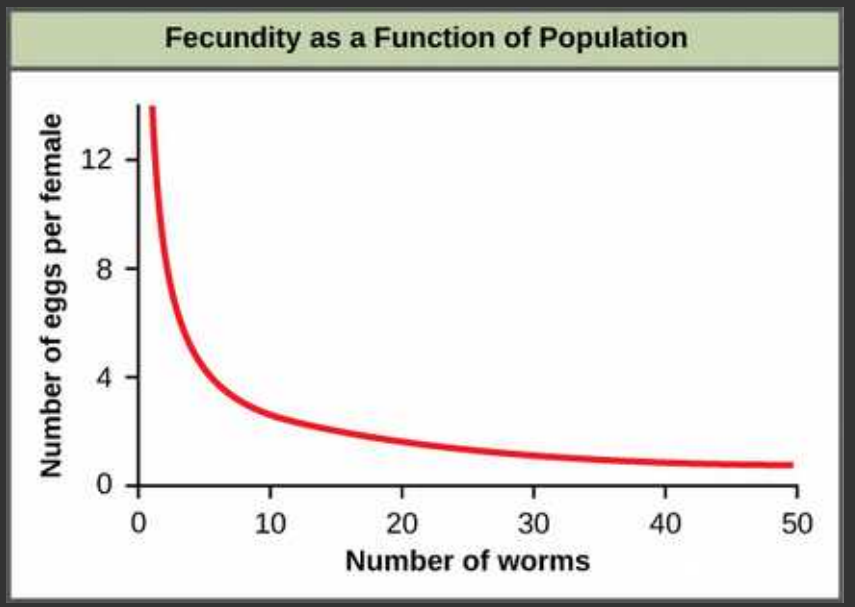
# Population demographics

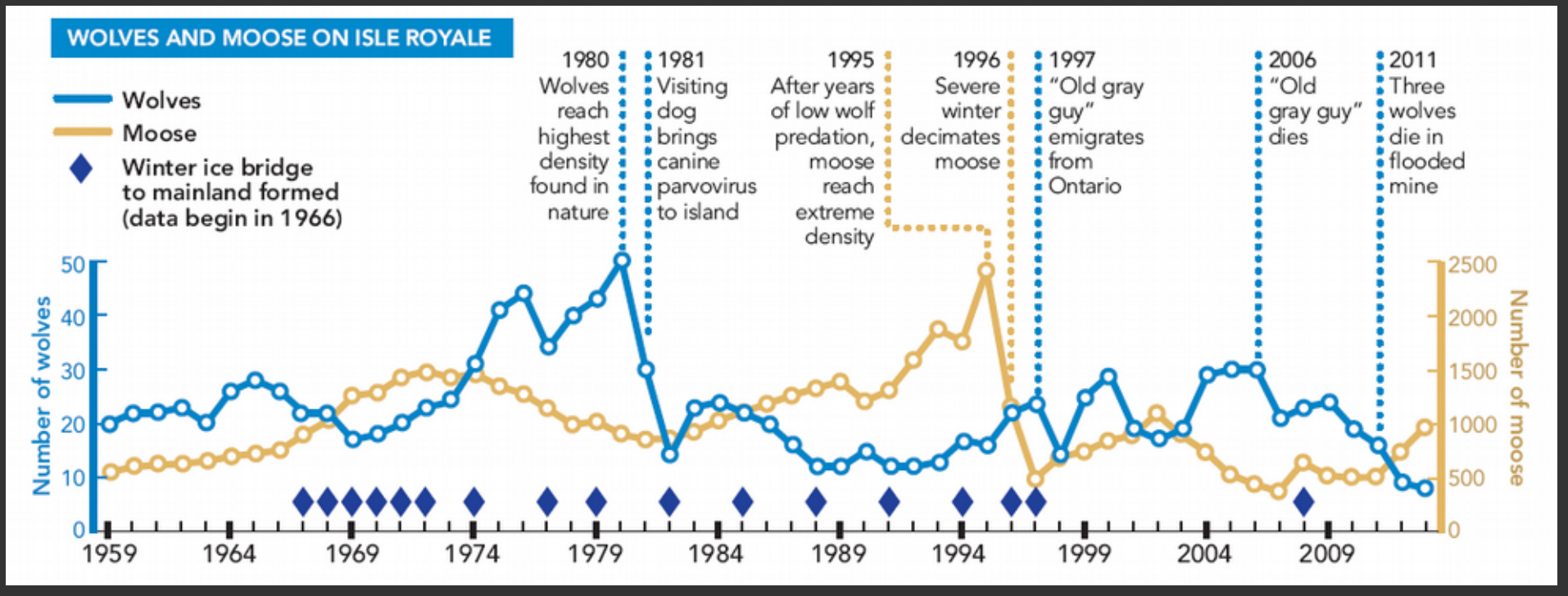
Suvivorship curves

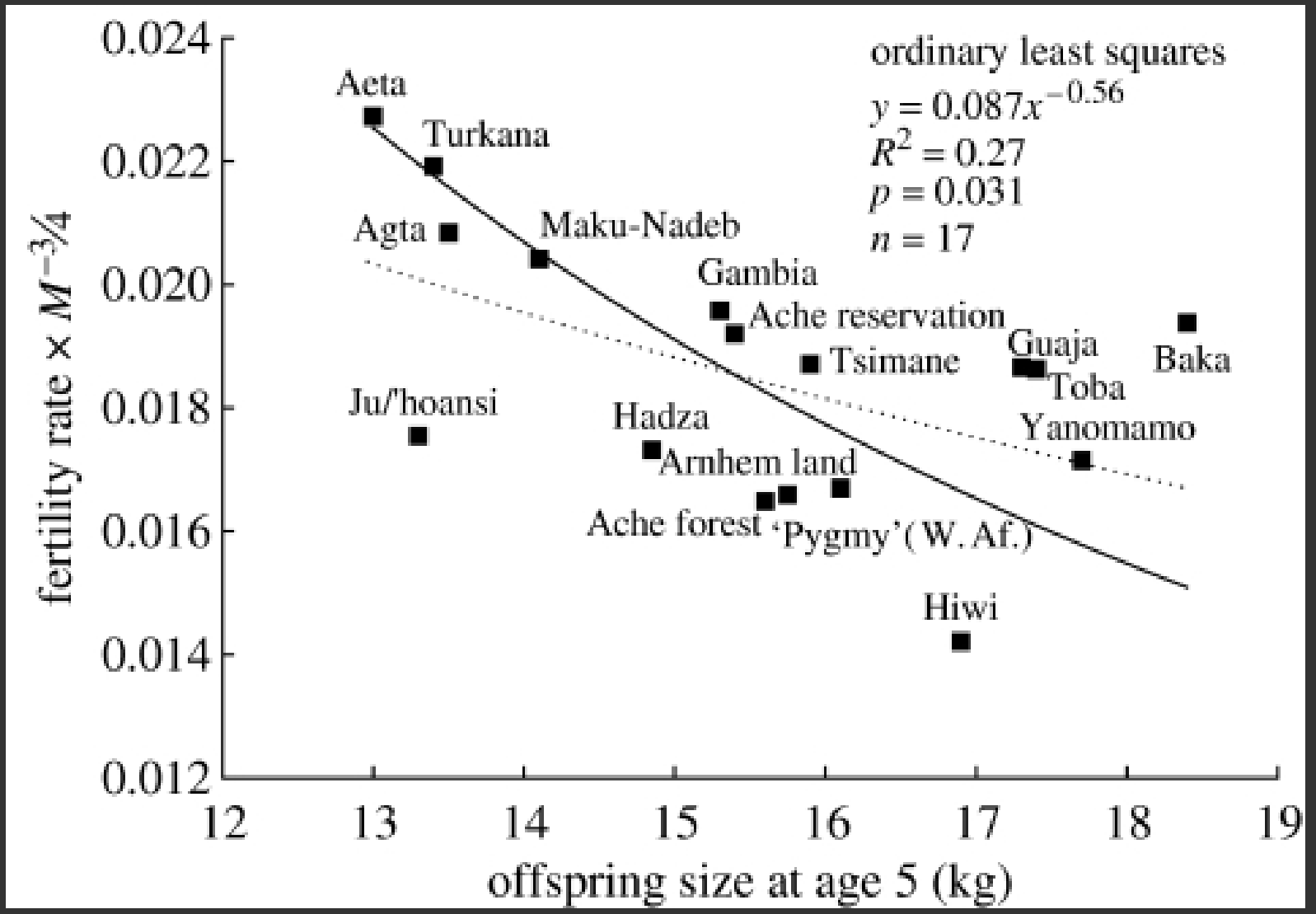


# What regulates population growth?



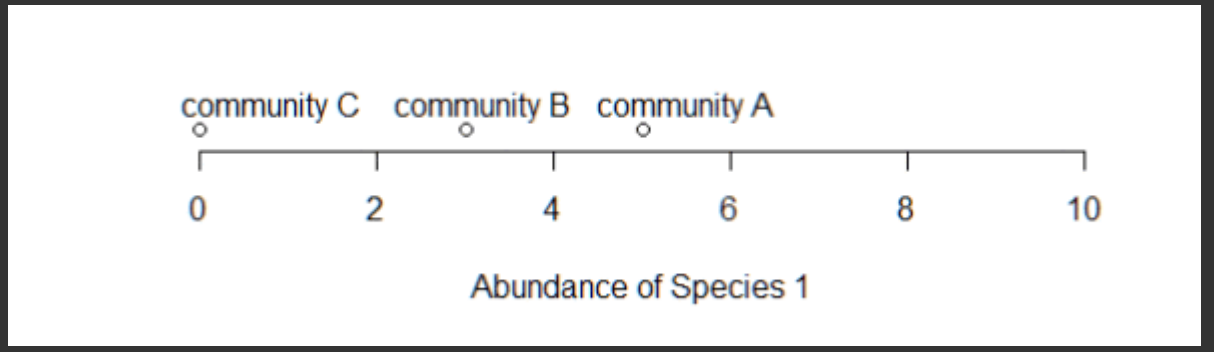





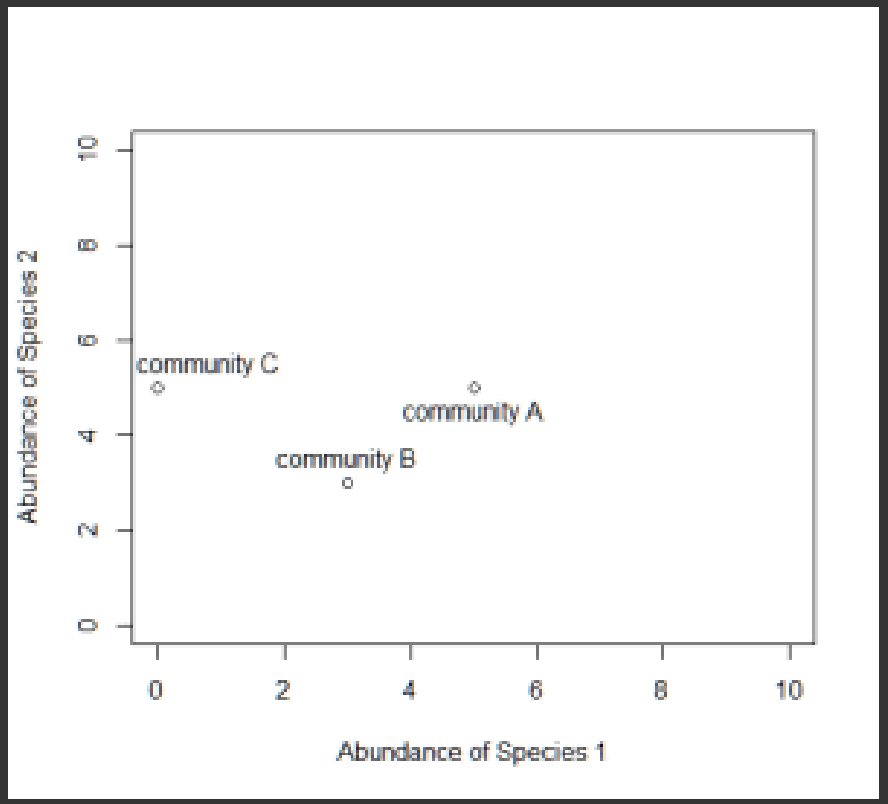

Energy-corrected fertility rate as a function of offspring size at age 5 across natural-fertility human societies.

# How do you compare whole communities across different places?

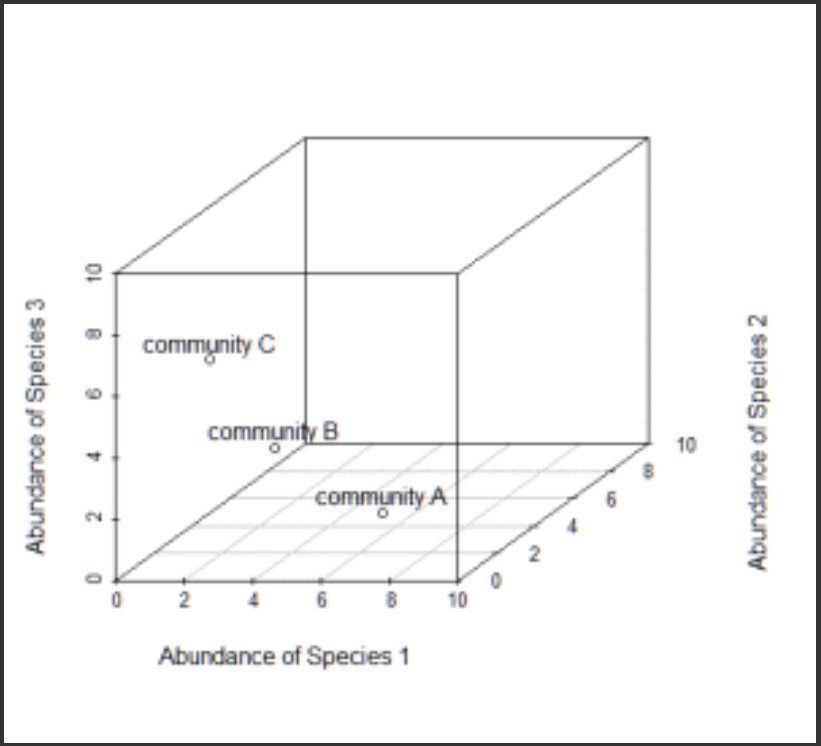
# Consider communities of only a single species



# 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