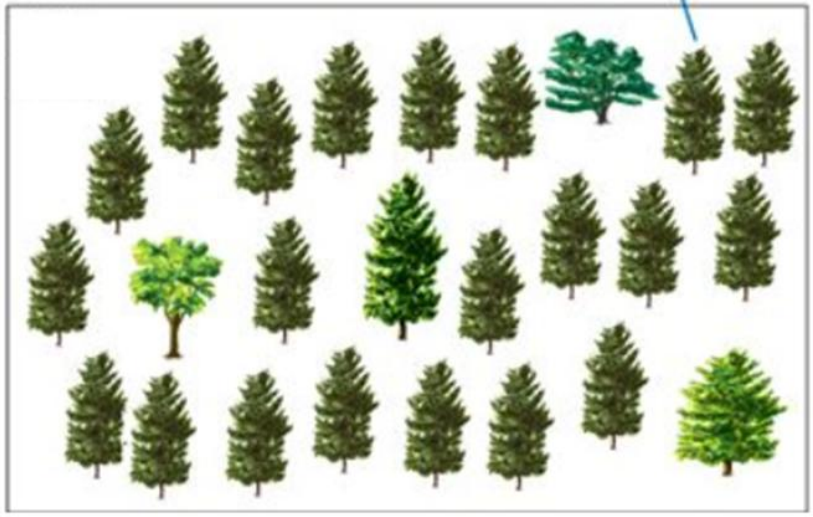
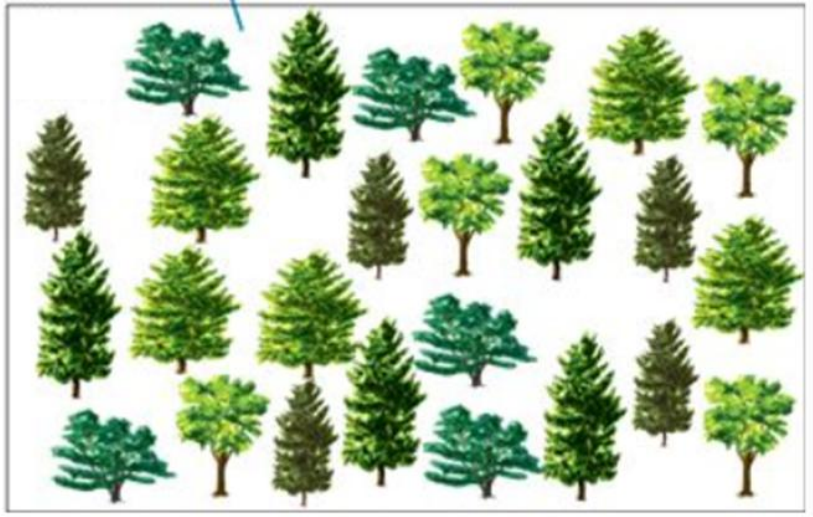
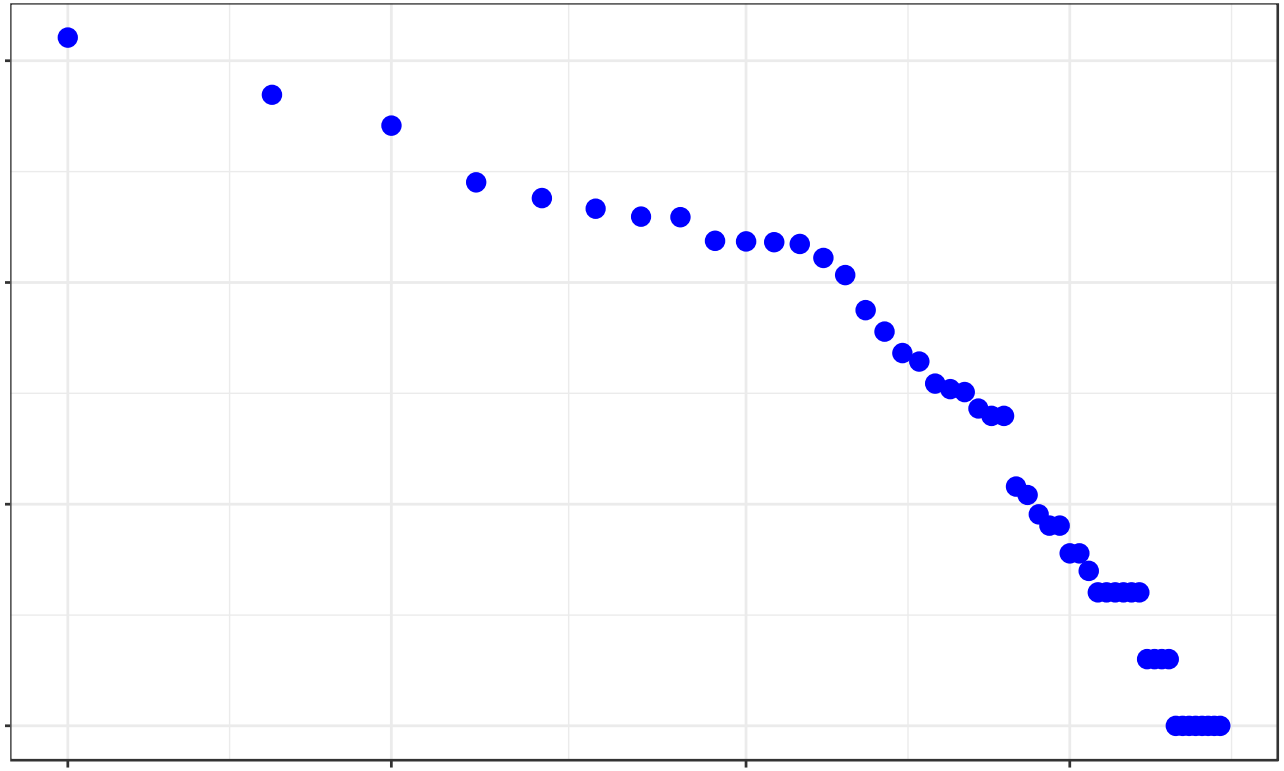






Community Ecology: Species Diversity



The ten principles of ecology

1. Evolution organizes ecological systems into hierarchies.
2. The sun is the ultimate source of energy for most ecosystems.
3. Organisms are chemical machines that run on energy.
4. Chemical nutrients cycle repeatedly while energy flows through an ecosystem.
5. dN/dt = B-X+I
6. dS/dt = D-X+I
7. Organisms interact – do things to each other - in ways that influence their abundance.
8. Ecosystems are organized into webs of interactions.
9. Human populations have an outsized role in competing with, preying upon, and helping other organisms.
10. Ecosystems provide essential services to human populations.

Topics for today

- Defining communities, and models of community development
- How do we quantify species diversity?
- Diversity across space

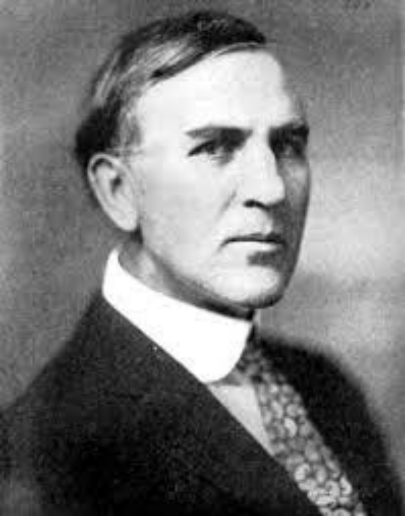
Topics for today

- **Defining communities, and models of community development**
- How do we quantify species diversity?
- Diversity across space

Defining a community

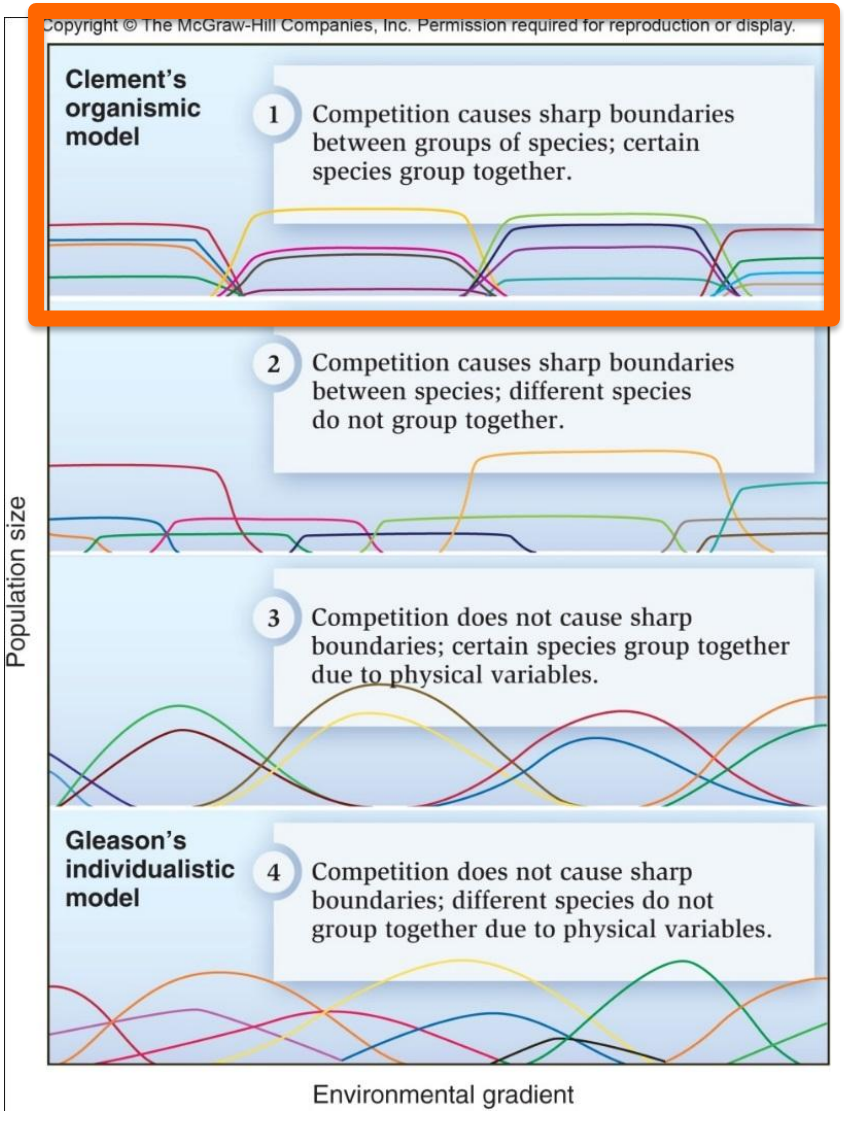
- Walk up or down a mountain and the environment and communities change
- Which is more important for predicting shifts in species composition: environment or competition?

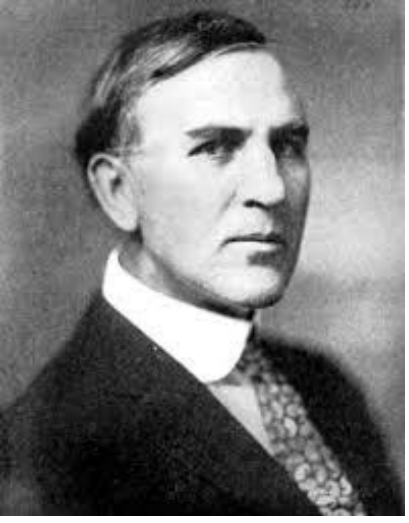




Organismic model

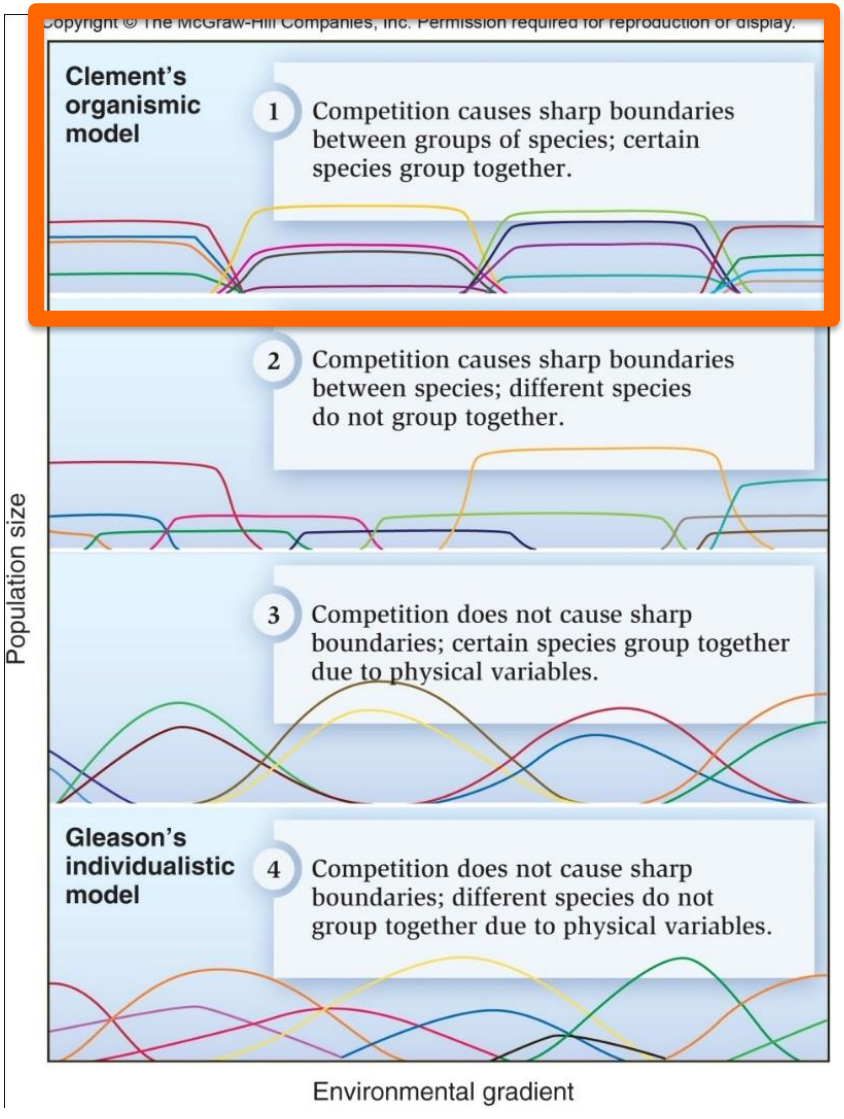
In the **organismic model**, community is considered to be equivalent to a superorganism, in the same way that the body of an animal is more than just a collection of organs.





Organismic model

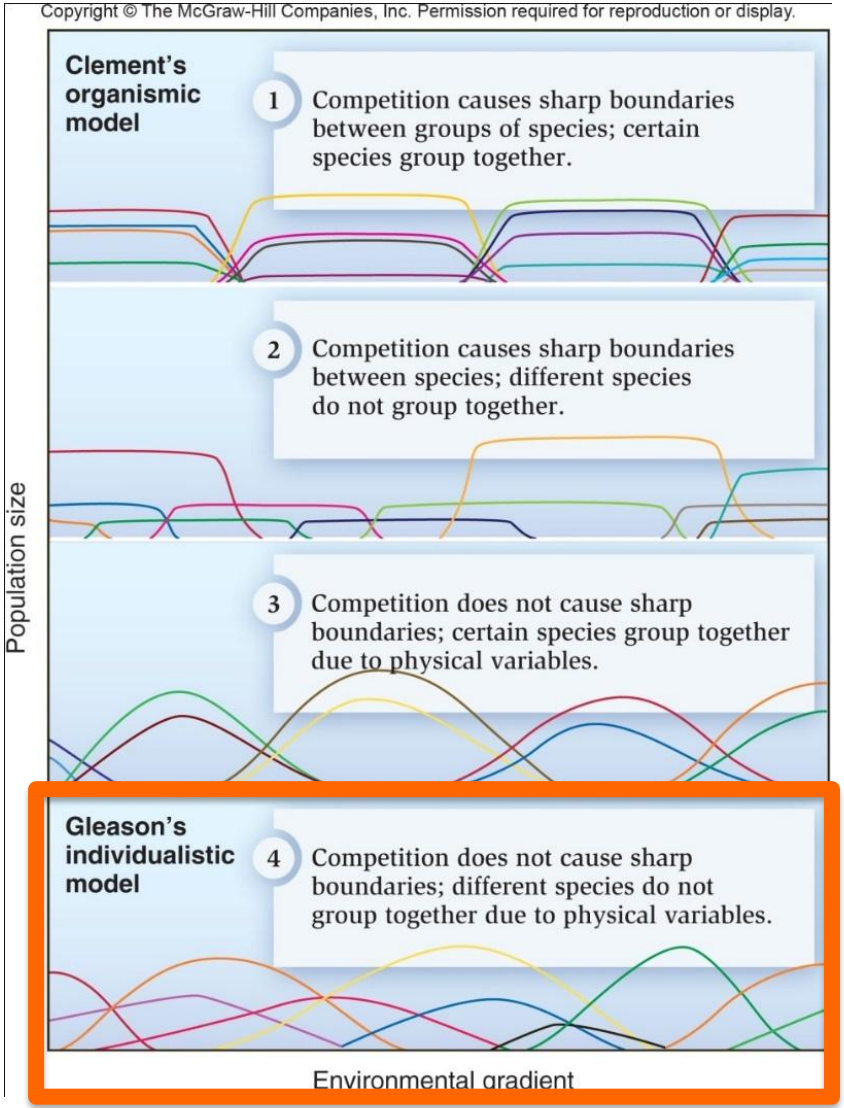
Frederic Clements (1905), suggested that a community was predictable with distinct associations of species. Separate communities were separated by sharp boundaries.



Individualistic model



In the **individualistic model** the assemblage of species in the community occur in the same place because of similarities in their physiological requirements and tolerances.



Tests of organismic vs. individualistic models

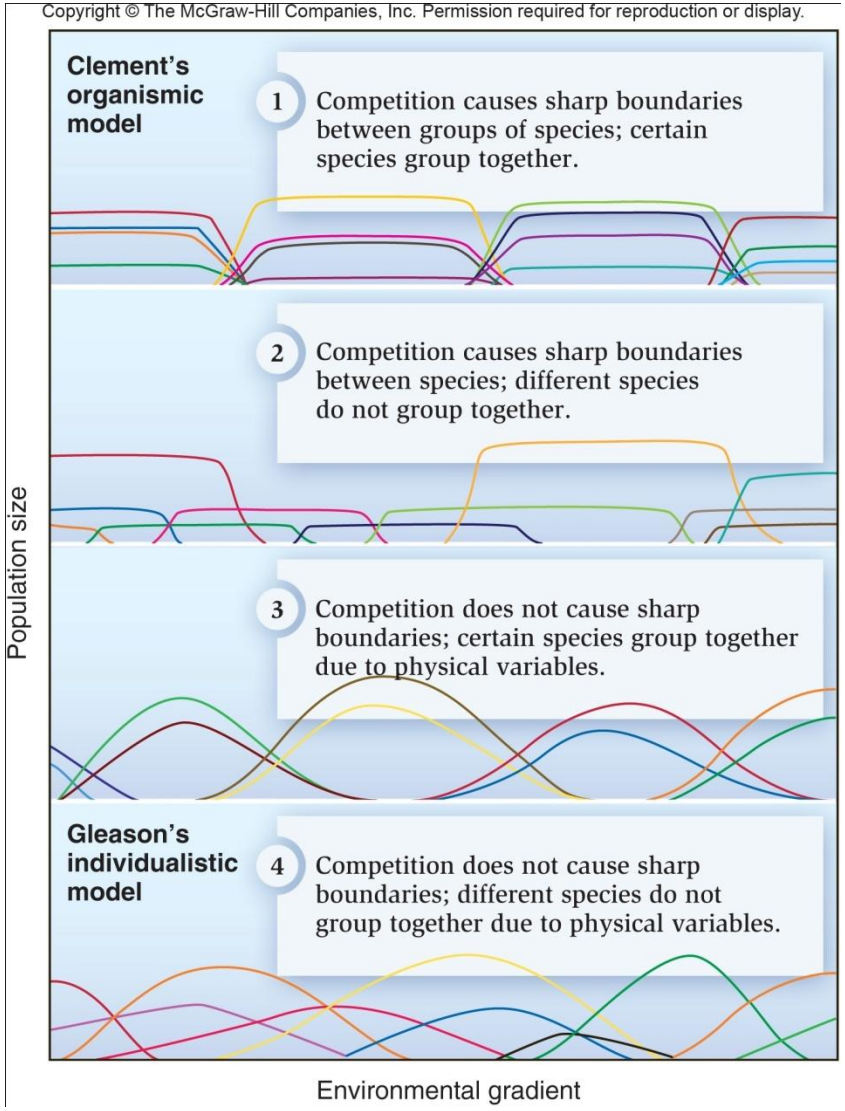
In an environmental gradient such as a moisture gradient on an uninterrupted slope of a mountain,

R.H. Whittaker proposed that four hypotheses could explain the distribution patterns of plants on the gradient.

Hypotheses of the nature of communities

Figure 17.1 Four hypotheses on how populations might relate to one another along an environmental gradient.

Each curve in each part of the figure represents one species and the way its population might be distributed along an environmental gradient such as a mountain slope.



Results

To test these possibilities, Whittaker (1970) examined the vegetation on various mountain ranges in the western U.S.

- The results supported the fourth hypothesis, that competition does not produce sharp boundaries between species and that adaptation to physical variables does not result in defined groups of species.
- Although species interactions strongly affect where some species are able to exist, the adaptations of individual species to the environment appears to be more important in determining most species' distributions than the interactions between species

Conclusions of the nature of communities

Whittaker's observations show that the composition of species at any one point in an environmental gradient is largely determined by factors such as:

- Temperature
- Water availability
- Light
- pH

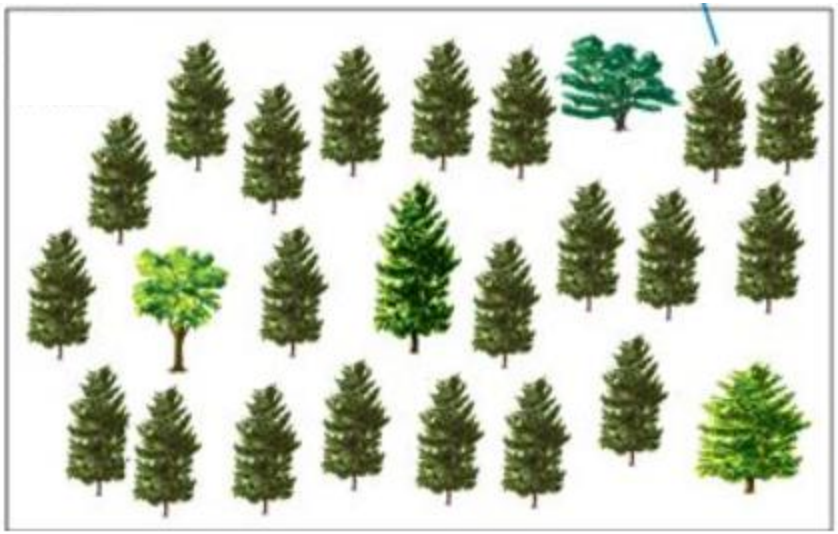


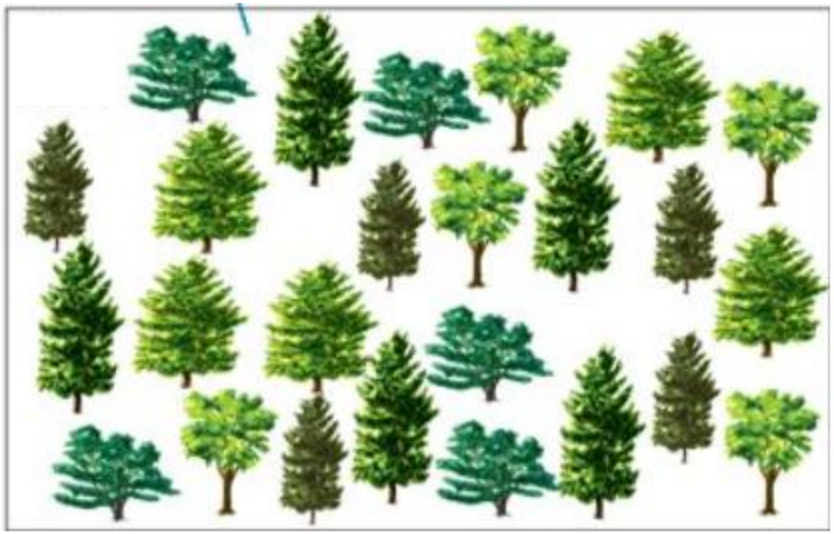
Topics for today

- Defining communities, and models of community development
- **How do we quantify species diversity?**
- Diversity across space

How do we quantify species diversity?

Which of these communities contains greater species diversity?





Measuring biodiversity

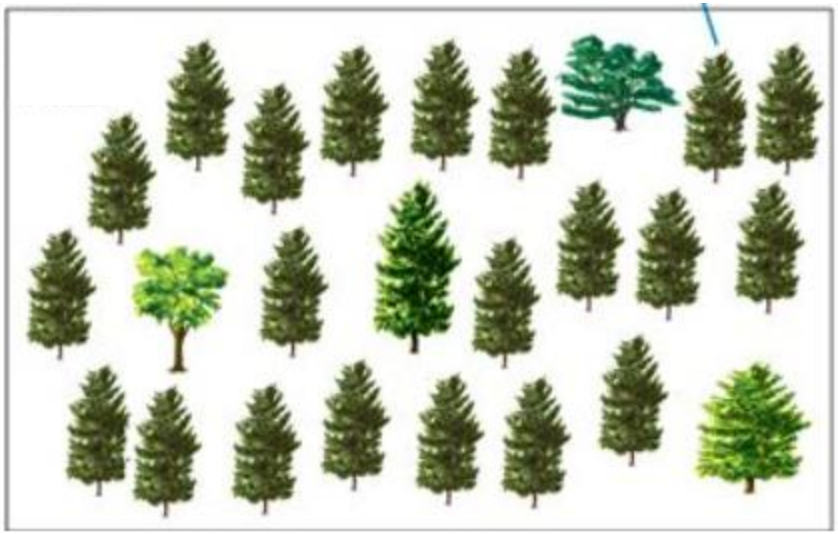
The biodiversity of a community in one location can be measured in different ways.

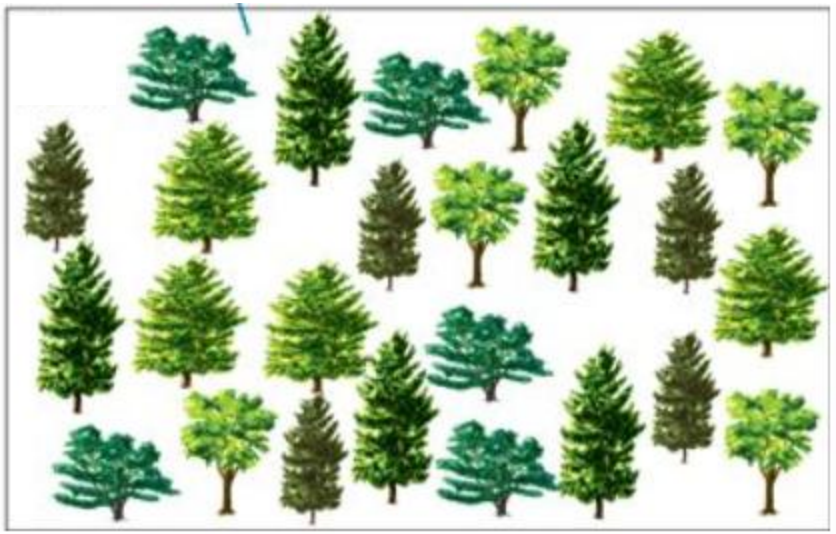
1) Species richness

2) Species dominance (or evenness)

The two communities would be equal in terms of species richness

Species richness = the number of species per unit area
(e.g. species per hectare)

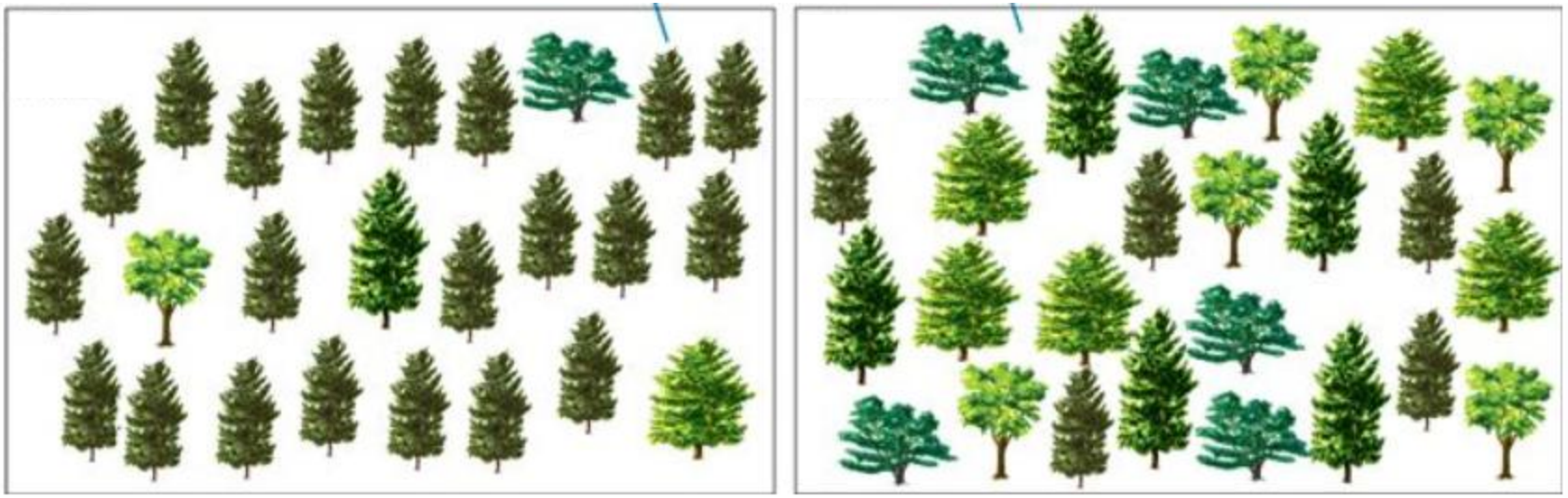




Both communities contain five species

The two communities differ in species dominance (or the inverse: evenness)

Species dominance is higher when one species is present in greater proportion than others



The community on the left has higher species dominance than the community on the right

There are many ways to calculate species dominance, but Simpson's dominance is one of the most common methods

Species dominance

Simpson's dominance index , D_S is calculated as follows:

$$D_S = \sum_{i=1}^{s} p_i^2$$

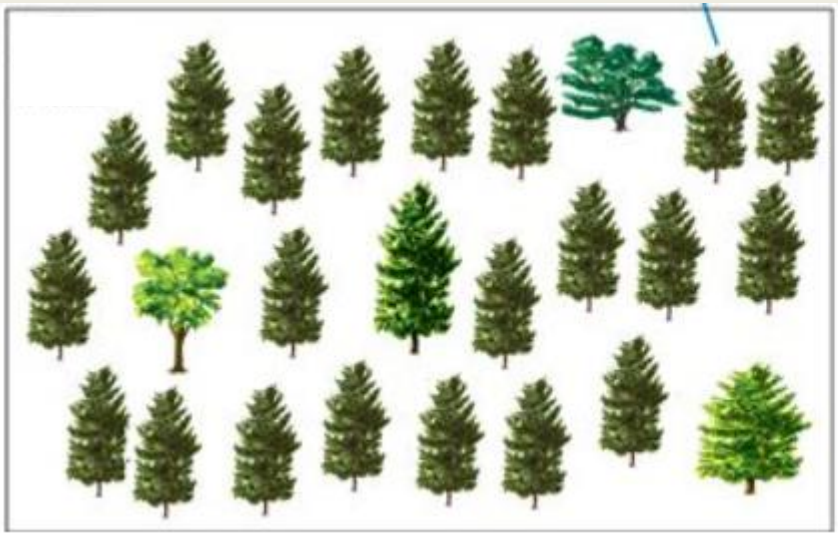
Perform this calculation for each species, from species 1 through species S, and sum all the values for all species.

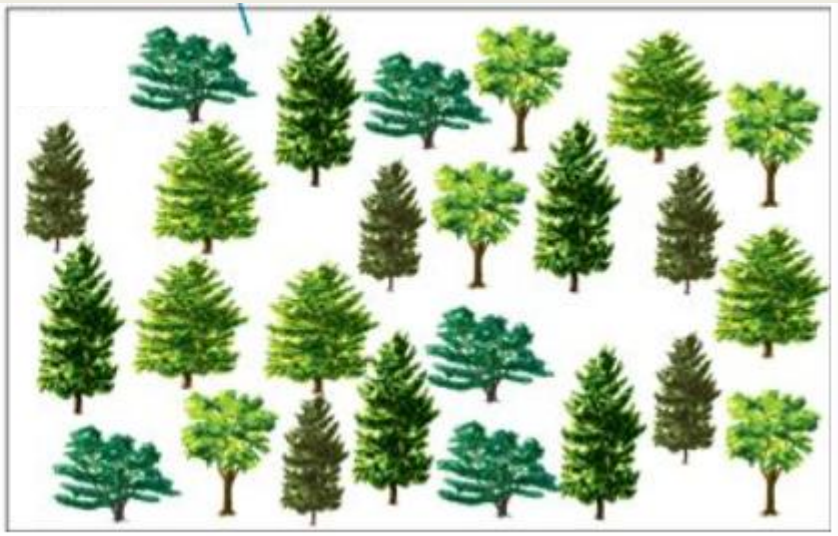
Proportion of individuals in each species.

- where *pi* is the proportion of individuals in the *i*th species.

(maximum of 1 in monoculture; minimum of near 0 with MANY species of equal abundance)

Species dominance





$$D_S = \sum_{i=1}^{s} p_i^2$$

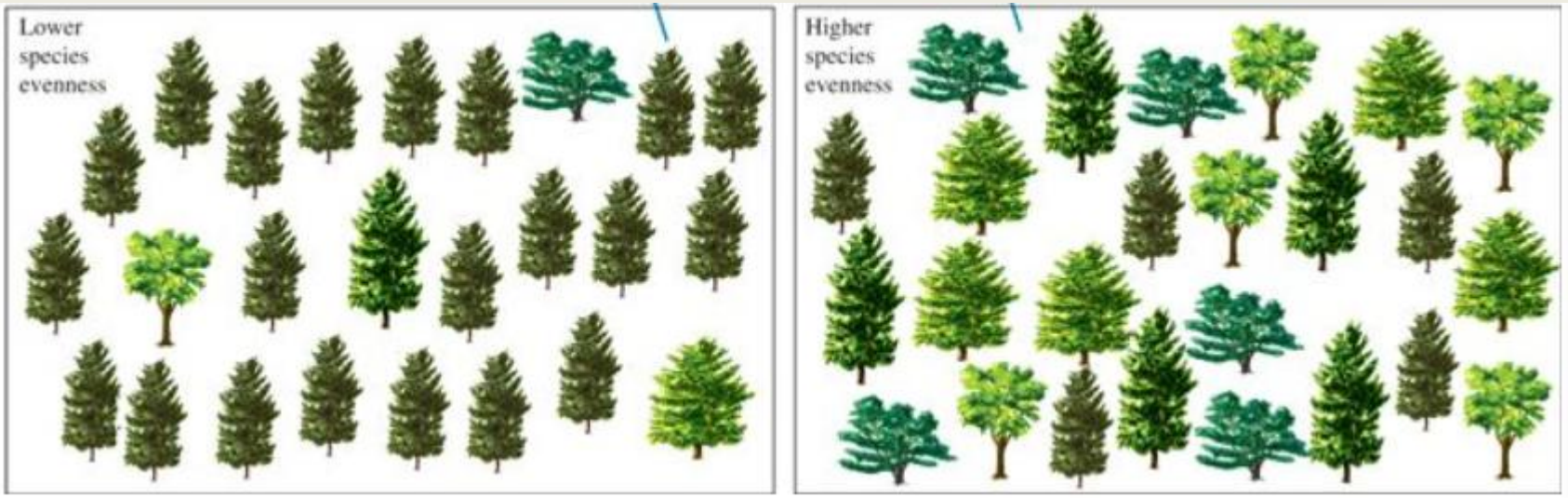
On the left, there are 21 individuals of the most common species and 1 individual of the other 4 species. The proportion (p_i) for each is p = 0.84 for most common species and 0.04 for the others.

On the right, there are 5 individuals of each species. p = 0.2 for each species.

Simpson's dominance = 0.7056 + 0.0016 + 0.0016 + 0.0016 + 0.0016 = **0.712**

Simpson's dominance = 0.04 + 0.04 + 0.04 + 0.04 + 0.04 = **0.2**

Species dominance



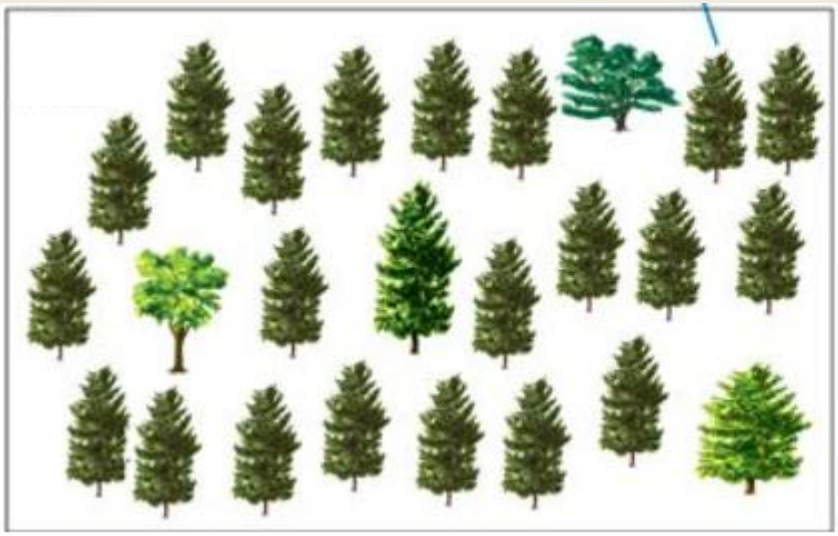
Another way to think about this metric is in terms of probability. What are the chances of picking two trees *of the same species* from each community?

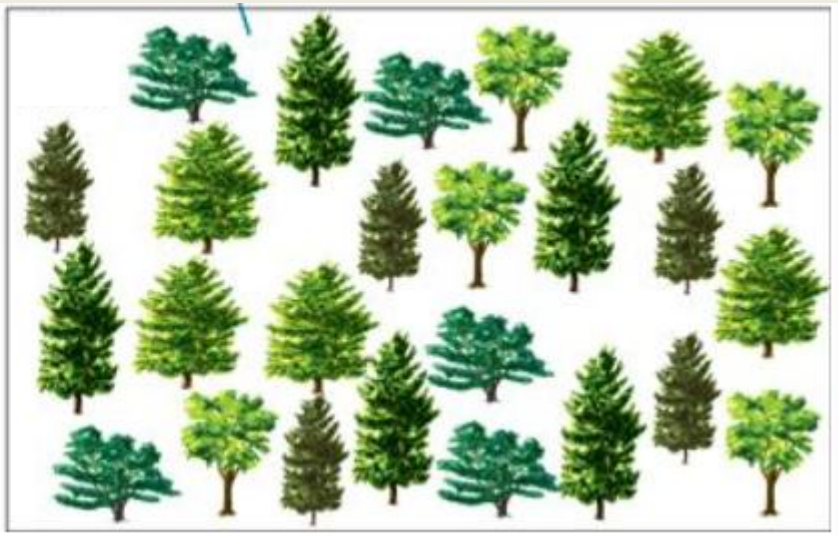
For community 1: p(species 1 AND species 1) = 0.84 * 0.84 = 0.7056

For community 2: p(species 1 AND species 1) = 0.2 * 0.2 = 0.04

Species evenness

Evenness measures give a higher value when species are present at more equal proportions





This is the best measure to use when examining evenness (Smith and Wilson 1996. A consumer's guide to evenness indices. *Oikos*)

$$\text{Simpson's evenness} = \frac{(1 / D_S)}{S}$$

S is the number of species in the community.

Please know how to calculate Simpson's dominance and evenness

Simpson's evenness = (1 / 0.712) / 5 = **0.281**

Simpson's evenness = (1 / 0.2) / 5 = **1**

Another way to describe changes in richness and evenness

Rank Abundance Diagrams

Visually describe the distribution of individuals among species in communities.

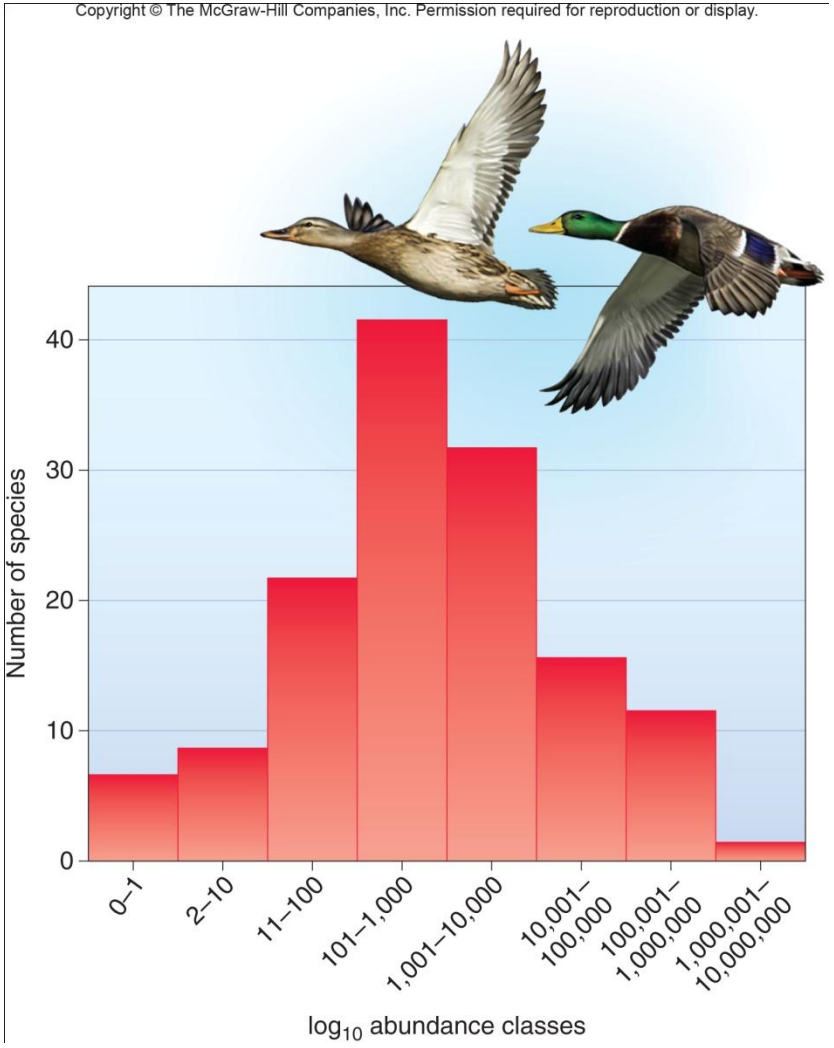
A more complete picture of a community is gained by plotting the proportional abundance of species, on a log scale, against **rank of abundance**.

Rank Abundance Diagrams

Figure 17.11 The lognormal distribution.

Species abundance plotted against log $_{10}$ abundance classes for British birds.
(Data from Williams 1964)

There are a few species that are very common, or very rare, and a lot of species that have an intermediate number of individuals.



Rank abundance diagrams

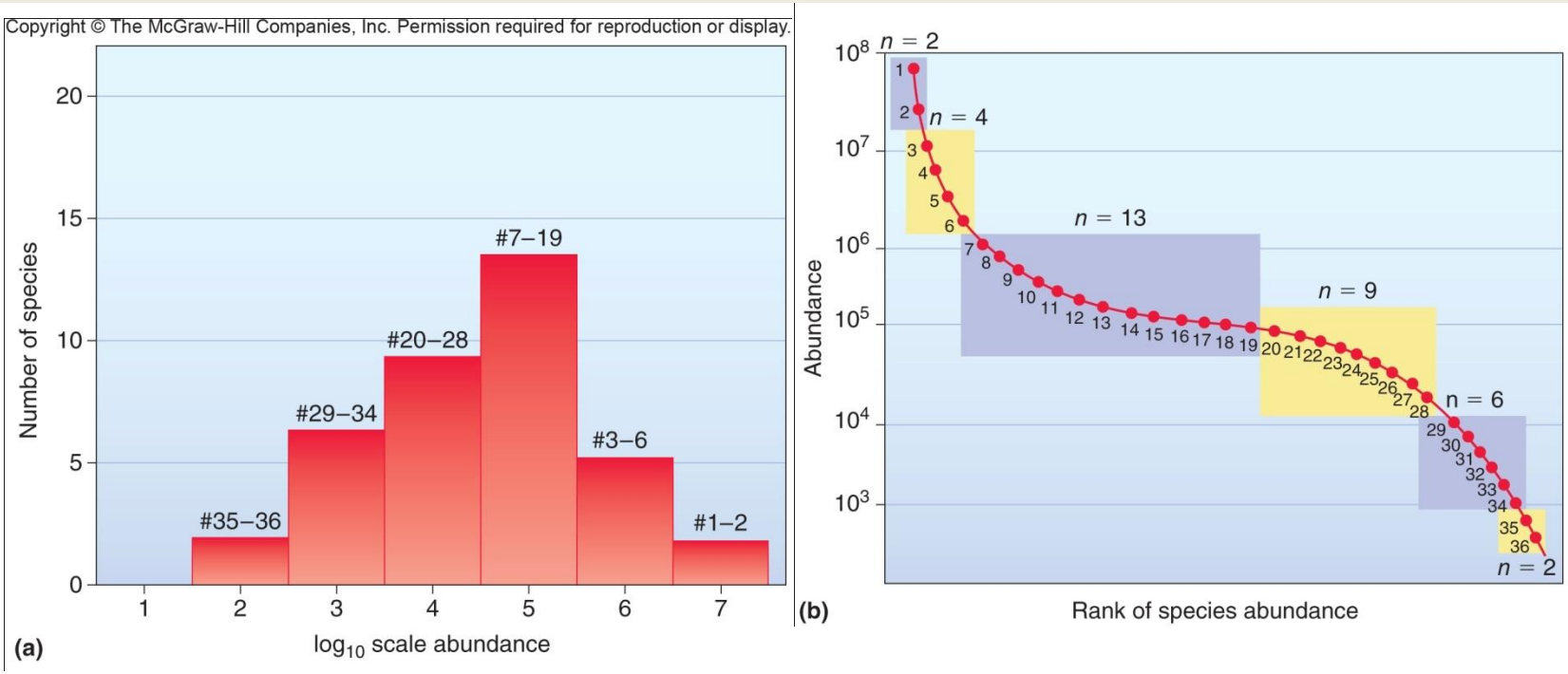
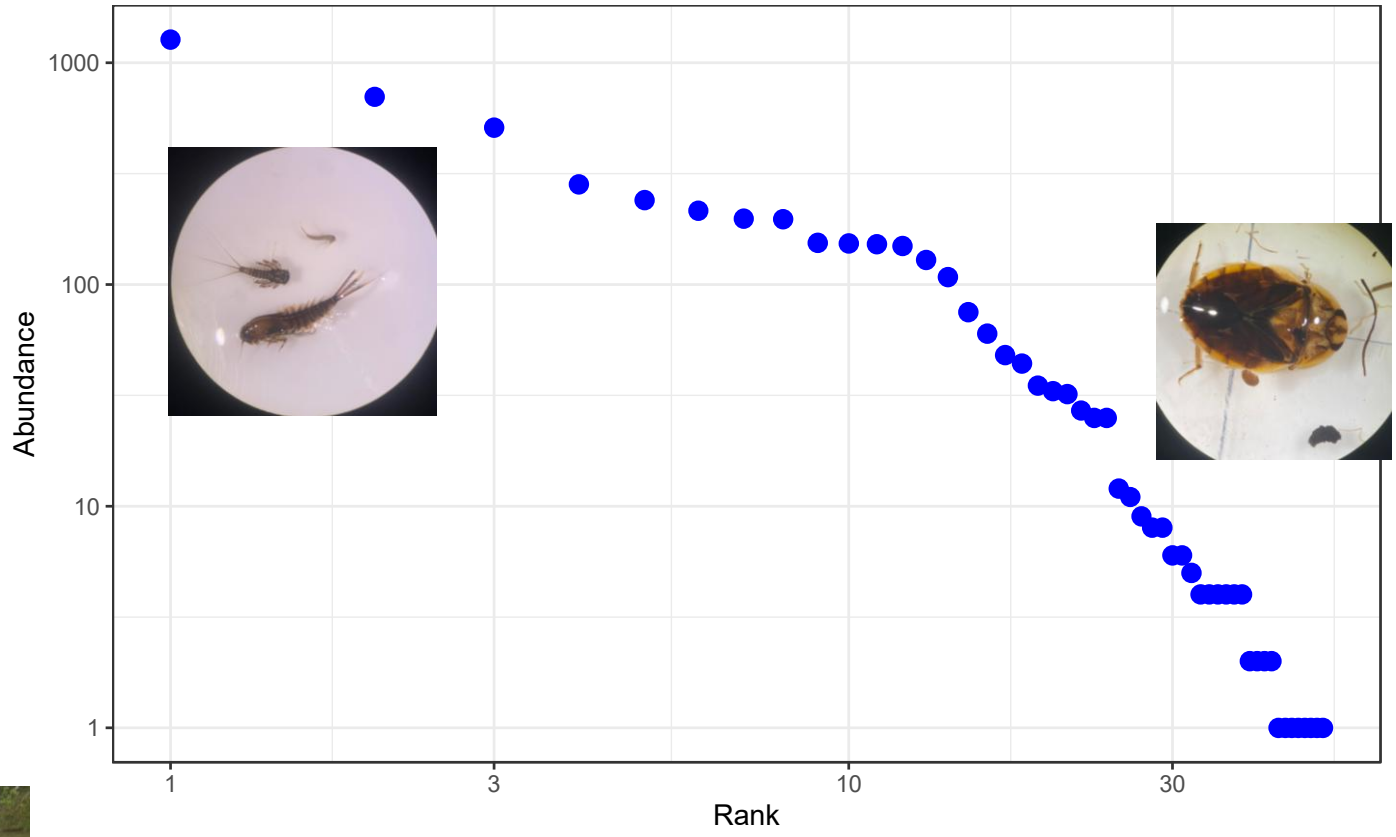


Figure 17.12 The lognormal rank abundance plot.

(a) Each species is given a number. We then group the species in abundance classes of $\log_{10}$. The result is a normal distribution: some species with few individuals (#29-36), some species with many individuals (#1-6), but most with an intermediate number of individuals (#7-28). **(b)** In the rank abundance plot, the abundance of each species is plotted on a logarithmic scale against the species rank, in order from the most abundant to the least abundant species.

Macroinvertebrate species diversity and abundance in the Niobrara River







Dailey et al., *unpublished data*

Main conclusion

Most communities have a few species that are very common, a few species that are very rare, and a lot of species that have an intermediate number of individuals.

Main points

1) What is a community?

2) How do we quantify species biodiversity?

3) **Biodiversity across space**

https://www.youtube.com/watch?v=kDmcxisClX4
Madagasgar

Biodiversity across the landscape

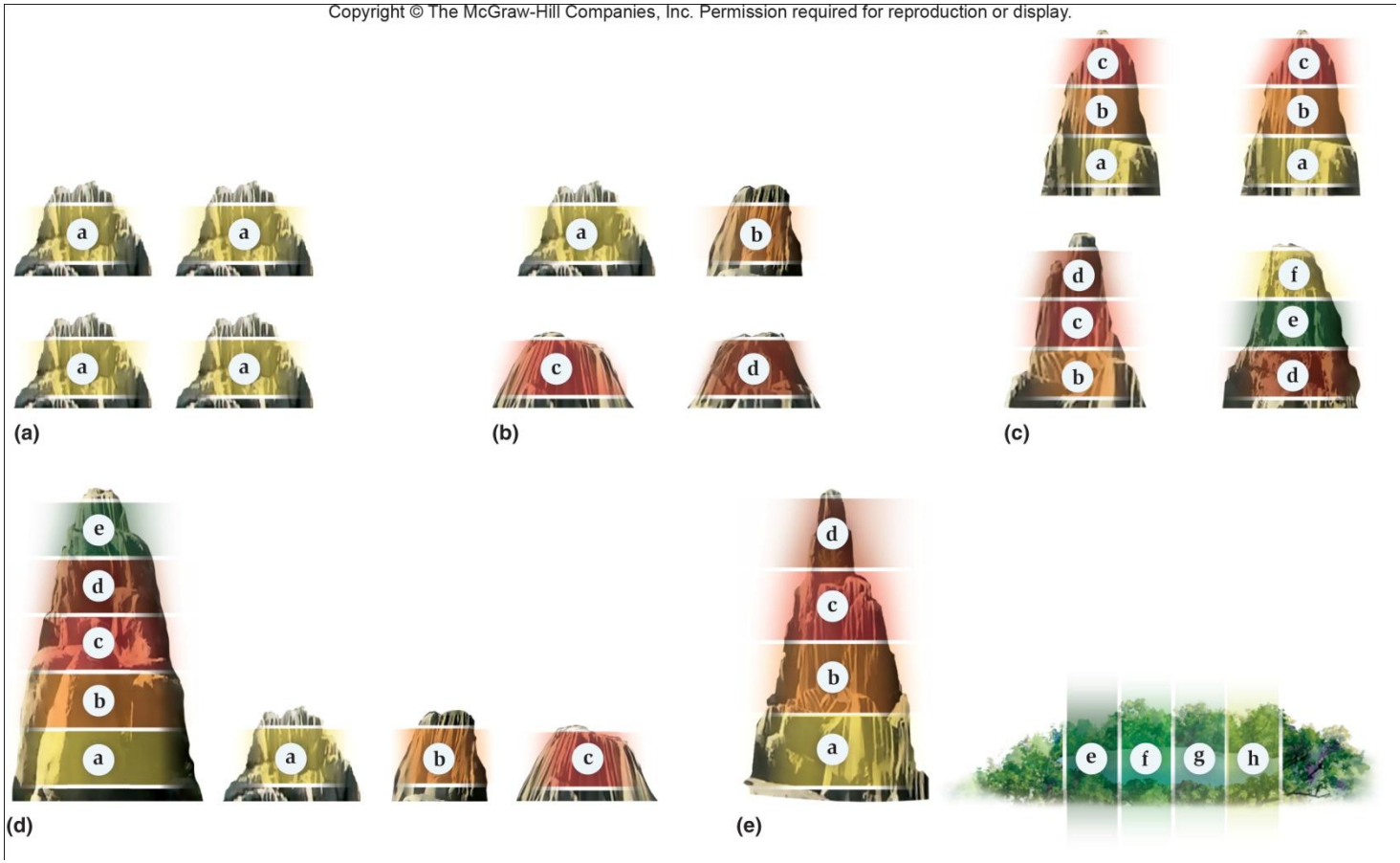


Figure 17.9 Local, site, and overall species richness.

Species diversity is lowest in site (a) and highest in site (e) with intermediate values in sites (b), (c), and (d). Each letter in the habitat is a different species…species a-h, and each mountain or forest is a different location.

Does site (i.e., diagram) (a), (b), (c), (d), or (e) contain a greater number of species?

Biodiversity across the landscape

Main point: To maximize γ diversity, you want to maximize BOTH α and β diversity.

Local site richness is called **alpha diversity** or **α diversity**.

The overall richness of an area is called **gamma diversity** or **γ diversity**.

The difference between sites in an area is called **beta diversity** or **β diversity**.

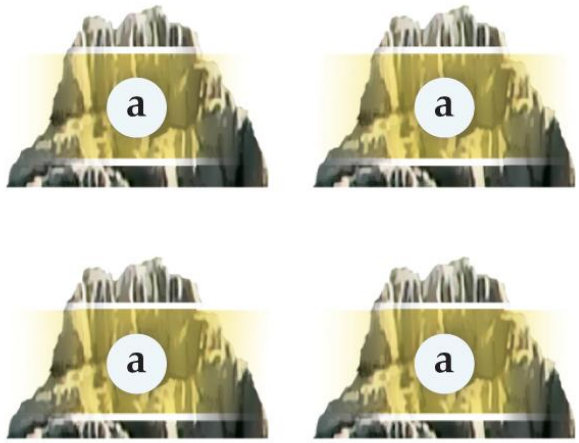
-The relationship between the three types of diversity is given by the formula:

α diversity x β diversity = γ diversity
Therefore, β = γ / α

Biodiversity across the landscape

Let's consider some examples of the relations between α , β and γ diversity.

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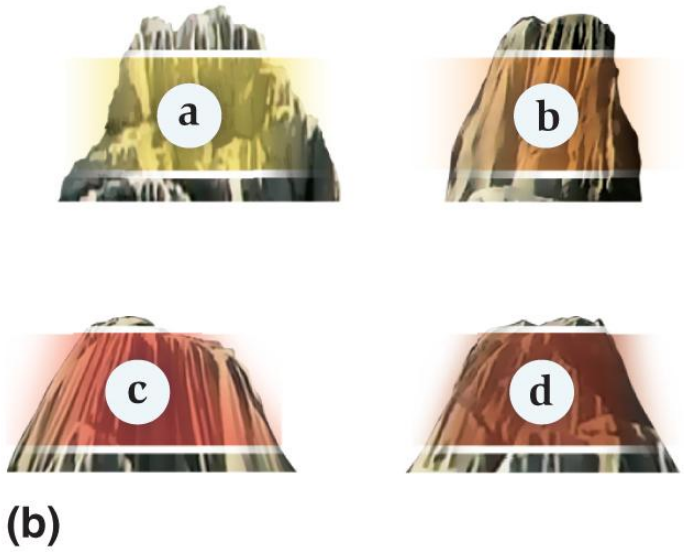


(a)

Region (a), there are four sites each with one species so α diversity = 1 at each site and γ diversity is also 1 because there is but a single species. β diversity = _____

Biodiversity across the landscape

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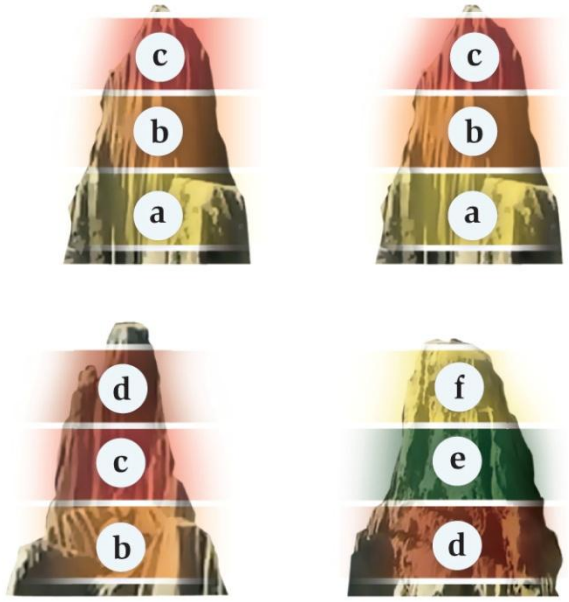
(b)

Region (b), α diversity also = 1 but each site has a different species so γ diversity = 4.

β diversity = _____

Biodiversity across the landscape

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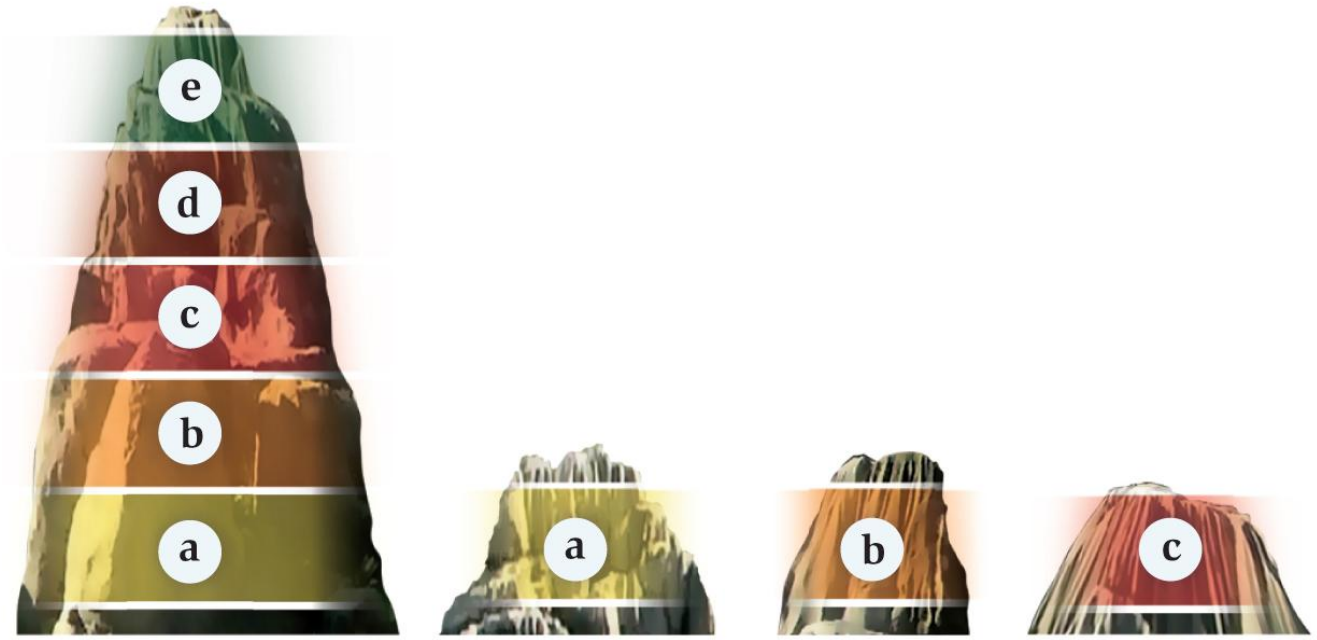


(c)

Region (c), α diversity = 3 species per site and γ diversity = 6 because there is a total of 6 species in the region. This gives a β diversity of 2.

Biodiversity across the landscape

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(d)

Region (d), 1 site has a high α diversity and the other sites have but a single species.

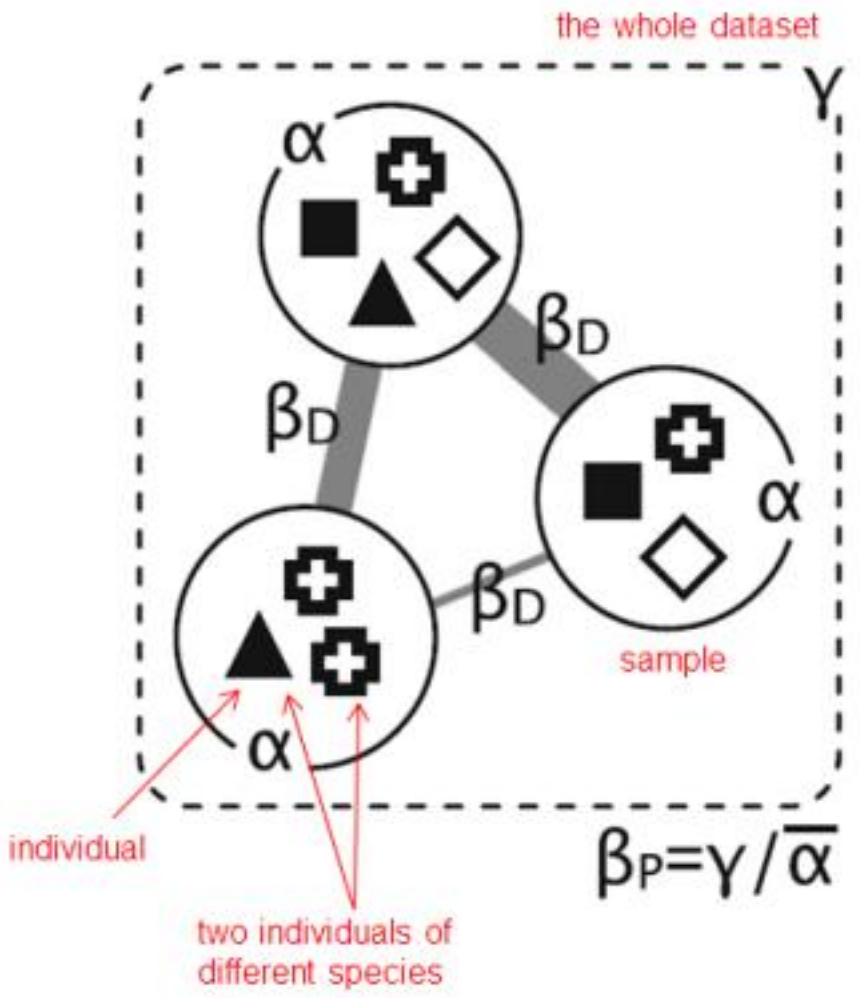
α diversity = _____

β diversity = _____ γ diversity = _____

Biodiversity across the landscape

Beta diversity can depend on the scale of inquiry

β_D = (dis)similarities between pairs of samples
β_P = proportional diversity, relationship between two scales of investigation



Jurasinsky et al. 2009

Biodiversity across the landscape

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Region (e), has the highest diversity of all, γ diversity = 8 species. There are two distinct sites each with 4 unique species (α diversity).

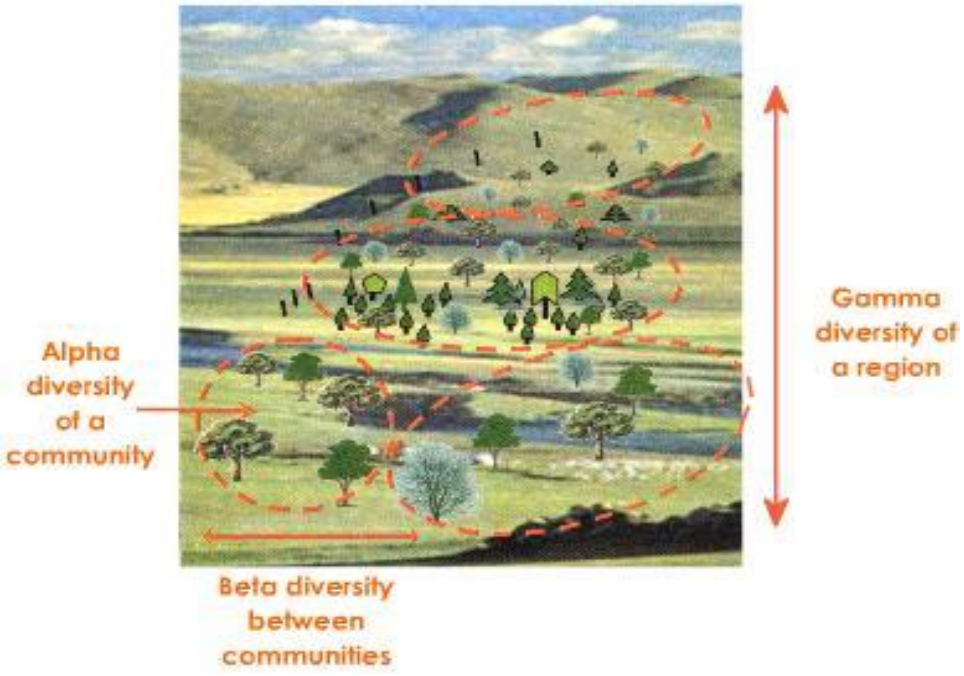
β diversity = _____

γ diversity can therefore increase due to increases in α or β diversity

Biodiversity across the landscape

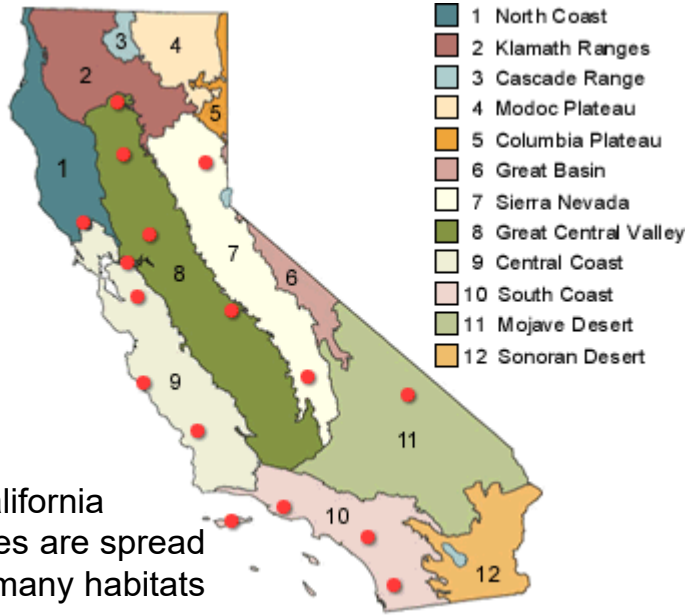


Biodiversity across the landscape



The greater the difference between habitats across the landscape, the more beta and gamma diversity should increase.

Organizations like The Nature Conservancy (TNC) that want to protect as many species as possible use these ideas when purchasing land. They try to maximize both alpha and beta diversity in their land purchases to thereby maximize gamma diversity.



TNC California preserves are spread across many habitats

Check your understanding

1. Discuss species richness and species dominance/evenness metrics and what they indicate about a community.
2. Compare and contrast the organismic model and the individualistic models of community assembly to Whitaker's observations on mountains.
3. Describe how lyme-disease prevalence may be affected by top-down population regulation.
4. What is a "trophic dead-end", and what conditions or characteristics could cause one to occur?