***Ecological Niches***

***Ecological Niche: 'the total of the adaptations of an organismic unit'***

***Niches identify the 'role of an organism in its community', or 'the way a species makes its living'.***

The niche of a species (or an individual) refers to the ways in which it *interacts* with its environment, so niches are closely related to environmental tolerance curves, but niches can have behavioral dimensions (e.g method of locomotion - running, swimming, flying) as well environmental ones (e.g temperature limits).

Can discuss the niche of an individual, population or species

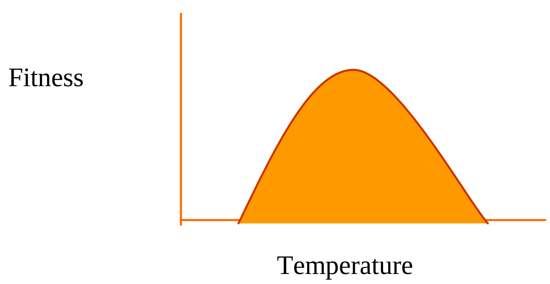
Data on niches can be used to:

1. Make comparisons of the composition and organization of communities.
2. Examine shifts in the behavior or ecology of one species in response to another species. (In particular, niche shifts are commonly used to study interspecific competition, based on Gause's Principle of Competitive Exclusion).

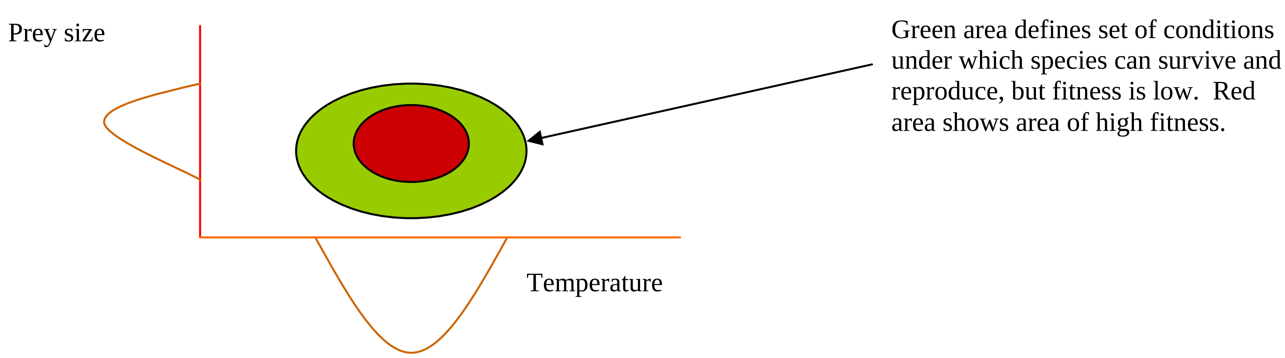
***Hutchinson's model of niche as a 'hypervolume':***

Niches can be described or defined by relating **fitness** or **utilization** to environmental variable (abiotic and biotic)

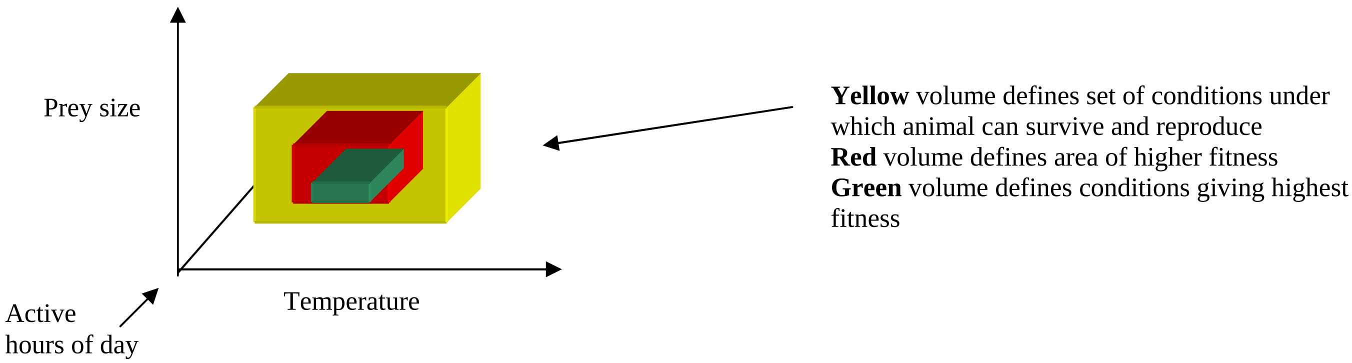
Start with a tolerance curve for one environmental variable:




Add a second variable that affects the animal's fitness




Then add a third variable that affects the animal's fitness:



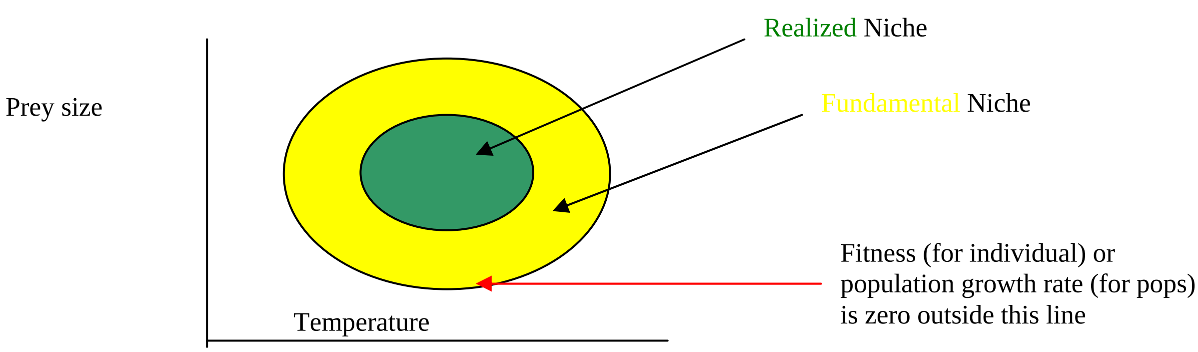

If you then add a fourth axis (and onward), the result is a hypervolume - a range if conditions defines by many axes, which defines the set of conditions under which the animal can survive and reproduce. Can refine to show 'fitness density' (as in 2-d example).

Hypervolume idea is good for illustration, but remember:

1. not all niche axes are environmental - some niche axes are behavioral (e.g. nocturnal vs diurnal activity pattern)
2. not all axes can be ordered linearly (e.g types of antipredator behavior), so they don't lend themselves to this graphical approach.

***Fundamental vs Realized Niche.***
**Fundamental niche** is the entire set of conditions under which an animal (population, species) can survive and reproduce itself.
**Realized niche** is the set of conditions *actually* used by given animal (pop, species), after interactions with other species (predation and especially competition) have been taken into account.

Sometimes FN and RN are termed **precompetitive** and **postcompetitive** niches, reflecting a traditional focus on interspecific competition's effect on niches.

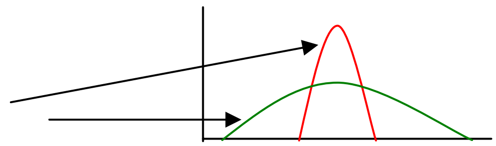


Note that:

1. FN ≥ RN
2. RN for different populations of same species may differ, because of differences in competitors and predators between locations.

***Niche breadth***

Specialist species have narrow niches
Generalist species have broad niches



These are relative terms - specialist and generalist describe the endpoints of continuous variation in the degree of specialization in resource use, behavior, and physiology.

Levins (1966) measure of niche breadth is:

Breadth = $B = 1/\Sigma p_i^2$

where $p_i$ = proportion of individuals that use resource *i*, or the proportion of diet of each individual composed of *i*.

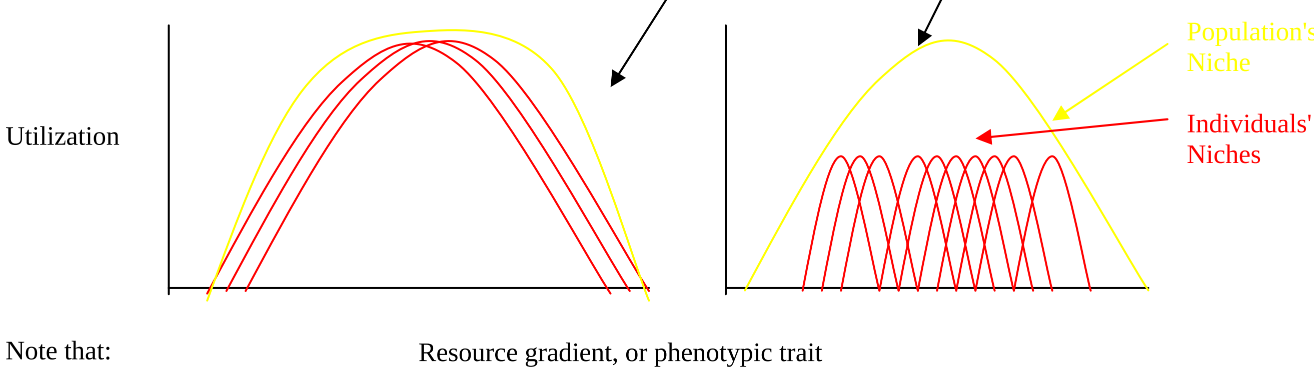
Because $p_i$ is in the denominator, species that use many resources will have large value of *B*, reflecting a generalist pattern of resource use.

***Between Phenotype and Within Phenotype Components of Niche Breadth***

If one knows the niche breadth of a population, it is not necessarily clear how *individuals* within that population use resources. For niche axes to do with food, a common approach is to examine stomach contents of many individuals and sum across individuals to describe the population's food niche. This assumes that individuals are similar w.r.t diet. However, individuals may (or may not) differ in use of resources.

One extreme is that all individuals use entire niche of population. **Within-phenotype** component of niche breath is large.

Other extreme is that each individual uses a narrow part of population's niche. **Between-phenotype** component of niche breadth is large.




Note that:

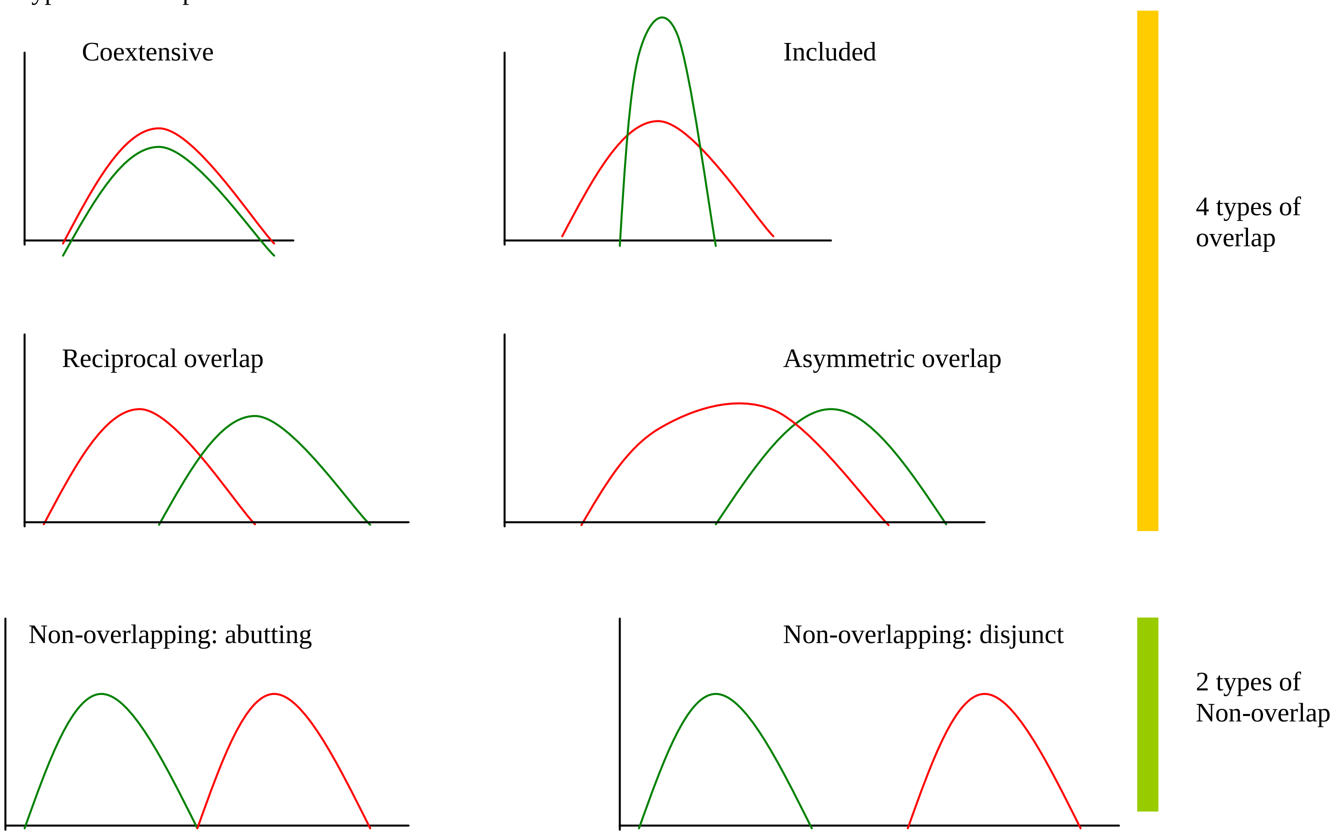
1. The niches of individuals can be very similar to the niche for the entire population, or just a small subset.
2. Individual's niches may change dramatically during a lifetime. Good examples come from species with indeterminate growth (e.g. lizards) where old individuals are much larger, and therefore take larger prey. Excellent examples from species with metamorphosis (e.g tadpoles are herbivores, frogs are carnivores).

(Overhead: Fig 7.26 a, b Begon et al.)

A: within phenotype component relatively large
B: between phenotype component relatively large

***Niche Overlap***

Types of overlap:




The degree and type of niche overlap can be used to assess interspecific competition. In general:

1. If niches overlap, *and resources are limiting*, then competition is currently occurring.
2. Abutting niches are an (indirect) indication that competition may have lead to niche divergence in the past.

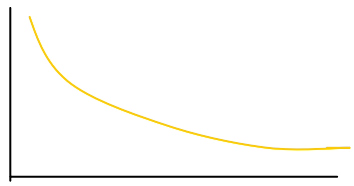
***Examples of use of niches to examine distribution and abundance of species:***

**I. Holmes' (1973) study of intestinal parasites in rats: interspecific competition**

The rat's intestine is the environment - this limits the number of niche axes and allows a simple study of niche relationships.

Tapeworms and acanthocephalans (spiny-headed worms) are the potential competitors, whose niches were studied. Both attach to intestinal wall and draw nutrients from blood.

There is an inverse relationship between position of attachment in gut and carbohydrate availability, with anterior positions most favorable:




Holmes studied position in gut as the major niche axis, in single-species and mixed infections.

Note: Single-species, low-density infection = *Ideal* niche (in absence of both inter- and intra-specific competition)

Single-species, high density infection = *Fundamental* niche (in absence of inter-specific competition, but intraspecific competition present)

Mixed-species infections = *Realized* niche ("post-competitive", in presence of intra- and inter-specific competition)

(Overhead: Fig 1. Colwell & Fuentes 1975 ARES 6:287)

1. In single species infections, tapeworms (generalists) have broader niche than acanthocephalans (specialists). At high density, acanthocephalans niche is included in tapeworm niche.

2. In single species infections, acanthocephalans specialize on the anterior portion of gut (where carbohydrates are more available) relative to tapeworms.

3. In single-species infections, use of niche broadens and flattens when population density is high. This is an example of ***niche expansion*** due to ***intraspecific competition***. Individuals are forced to use less-than-optimal parts of niche as population density increases. This is esp. true for tapeworms

4. Low density tapeworm infections: niche centers on the anterior portion of the gut, so tapeworm's ideal niche overlaps heavily with that of acanthocephalans. Strong potential for interspecific competition.

5. Mixed infections: Acanthocephalans niche narrows, centered on anterior portion
Tapeworms niche narrows, centered on posterior portion.

This is an example of ***niche contraction*** due to ***interspecific competition***. Shift from FN to RN in presence of interspecific competitors.

Consistent with interpretation that:

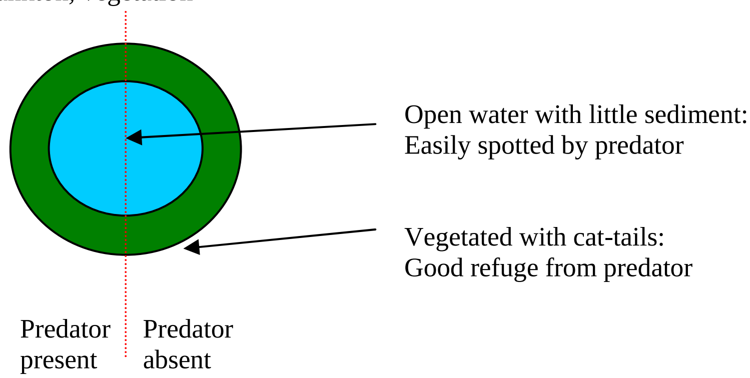
A. Specialist (AC) is able to exclude generalist (TW) from best habitat.
B. Generalist (TW) is able to persist after shifting to suboptimal habitat to avoid competition.
C. Competitive coexistence occurs, because species with included niche is better than generalist at using the overlapping niche space.

Holmes confirmed these conclusions with experiments in which he let one species establish an infection, then introduced other species.

A. Introduce AC into a TW infection: the tapeworms are displaced from anterior part of gut
B. Introduce tapeworms into acanthocephalan infection: no shift in the attachment sites of AC

## II. Werner's study of bluegill sunfish: interaction between food type and predator avoidance

1. Modified small ponds at Kellogg Biological Station in Michigan to provide **two distinct habitats**:
2. Stocked ponds with **3 size classes of bluegills**: S, M, L
3. Divided pond into halves with net and **introduced predator (largemouth bass) into one half only**
4. Three food types: benthos, plankton, vegetation




(Overhead: Table 1 Werner et al 1983, Ecology 64:1540-1548)

Results:

1. In absence of predator: S, M and L bluegills all prefer benthos as food, and use habitats similarly
2. In presence of predator:
   A. L bluegills not vulnerable to predation, and their diet is not changed
   B. M bluegills, little vulnerability, little shift in diet (take more plankton, 2nd best food type)
   C. S bluegills, highly vulnerable to predation when in open water. Shift to foraging in vegetation, the environment with lowest energetic return

(Overhead, Table 2 Werner et al.)

3. The shift in food utilization is reflected in growth rates.
   A. M bluegills - no $\Delta$ in growth rate when predator is present/absent
   B. S bluegills - significant $\downarrow$ in growth rate when predator present
   C. L bluegills - significant $\uparrow$ in growth rate when predator present - due to reduction in use of benthos by S bluegills, which reduces exploitation competition for food.

## III. Hairston's study of salamanders: interspecific competition.

1. Found in observational study that two species of salamanders, *Plethodon jordani and Plethodon glutinosis* were isolated by altitude in Smoky Mtns. Greater overlap in Balsam Mtns.
2. Suggests that **resources were more limited** in Smokys than in Balsams.
3. Also suggests **competitive exclusion** of *glutinosis* by *jordani* in Smokys (because *jordani* does not shift its altitude range between the two sites, but *glutinosis* does).

(Overhead: Fig 1, Hairston 1980 Ecology 61: 817-826)

Conducted experiments in which he removed one species and noted response of other species.

Results:

1. Remove *jordani*: strong $\uparrow$ in population density of *glutinosis*
2. Remove *glutinosis*: weak $\uparrow$ in population density of *jordani*

The difference in response between **specie***s* illustrates that competition is asymmetric, and *jordani* is dominant competitor as predicted.

1. Effect of removals in Smokys is strong, Effect of removals in Balsams is weak

The difference between **sites** illustrates that the intensity of interspecific competition, and its effect on altitudinal niche, depends on degree to which resources are limited.

## III. Dayan's studies of carnivore guilds: character displacement.

Guild = a set of species, usually phylogenetically close, that have similar ecology, play similar roles in a community.

Community = a set of populations occupying same area

If interspecific competition has been a strong force affecting the niches used within a community, then the members of a guild should not have heavily overlapping niches, at any given location.

A given species might occupy different niche in different places, so that two member of a guild CAN occupy same niche space. But competition should ensure species within a guild do not occupy same niche space within a single community.

Dayan examined skull morphology of carnivore guilds, using the logic that canine diameter and skull length determine the set of prey that a carnivore can kill.

(Overheads: Dayan 1996, Figs 7.1, 7.2, 7.3. Begon et al. Fig 20.4)

Dayan found that for most guilds (canid guild, felid guild, mustelid/viverrid guild), the guild members are less similar than expected by chance. This is indirect evidence that competition has reduced niche overlap through evolutionary time.

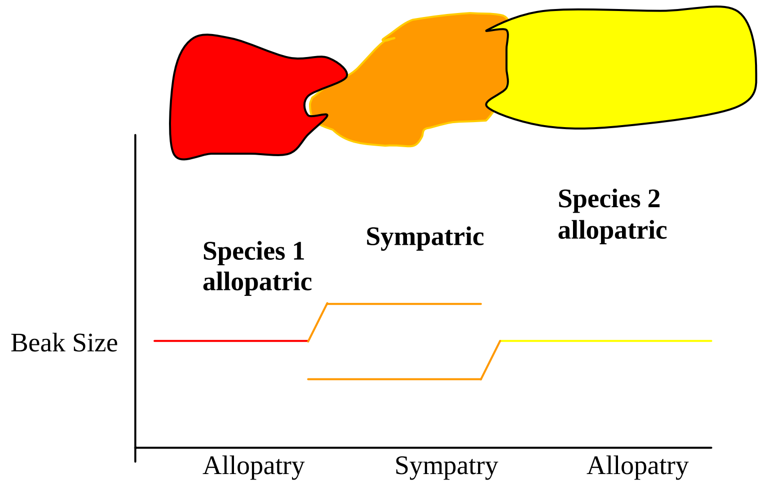
There are two serious difficulties with the use of niche overlap to study competition:

1. Niches may be non-overlapping due to competition, or for reasons that have nothing to do with competition.

(Overhead: Begon et al. Fig 20.9 - recorder 'guild' but even this might be due to a type of competition)

2. **The Ghost of Competition Past**: Species that do not currently compete may have competed in the past. Thus, even though competition is not active, it may have been an important force in structuring niche breadths and overlaps in the evolutionary history of a pair of species.

The best solution to these difficulties is to study potential competitors in areas of sympatry and allopatry. (Sympatry = species both found in same place. Allopatry = only one species occurs).




If a pair of species have similar niches in allopatric areas, and dissimilar niches in sympatric areas, this is good evidence for **character displacement**, which is a shift in niche to avoid interspecific competition.

Can also use **translocation experiments** to shift individuals from areas of allopatry to areas of sympatry and vice versa, to test for expected shifts in resource use. This is a strong approach because it is experimental, but for short time scales it can only be used to test for displacement of flexible aspects of niche, e.g. behavior or resource use (would need a loooong time to test for character displacement of morphological traits, unless using a species - e.g. inverts - with short generations).