Host specificity of parasites

Definition of host specificity

- The extent to which a particular parasitic taxon is restricted to a number of host species
- A real property of parasites - it occurs repeatedly in different populations of the parasite
- It is the result of evolutionary events and given ecological conditions
- Specialist versus generalist concept

Specialist (specific species) – on/in one host species

Generalist – on/in two or more host species

Basic host specificity

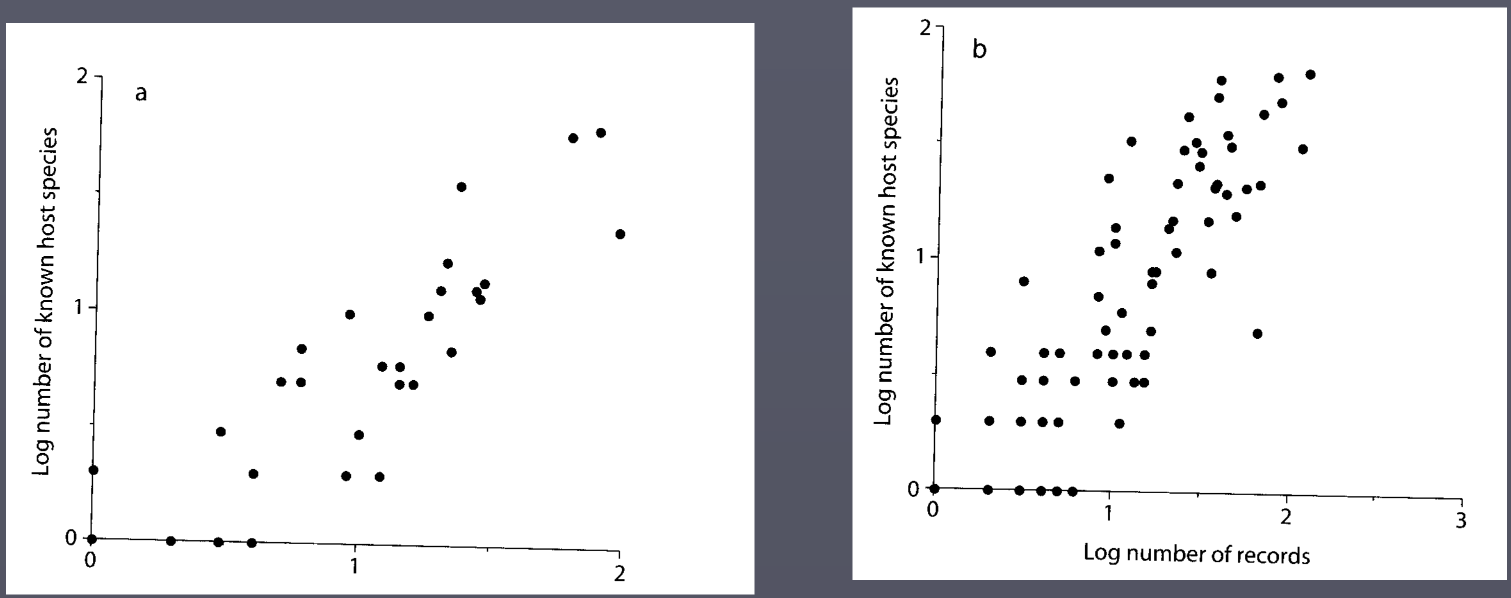
- Host range – measure of host specificity, number of infected host species by a given parasite species
- High host range = low host specificity
- Each of two species parasitize the same number of host species. Do they exhibit the same host specificity?

- Basic host specificity – number of host species infected by a given parasite species

- Ecological availability of host species, phylogenetic relatedness of host species, geographical distribution of host species

Effect of sampling on host specificity

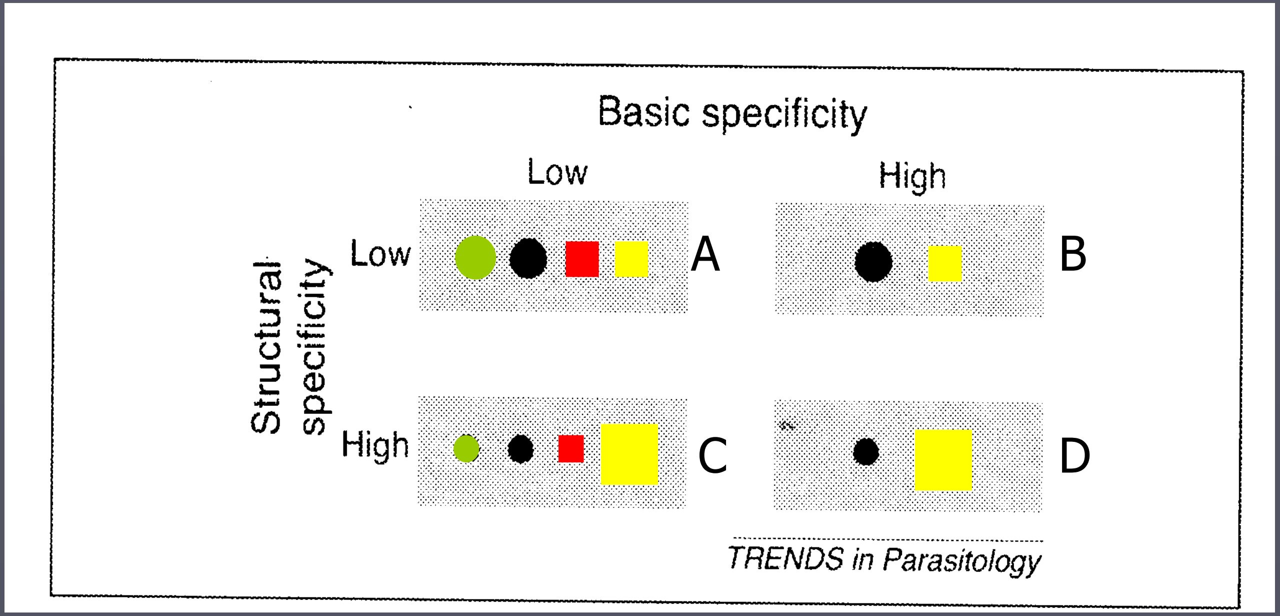
- High host specificity - a possible sampling artifact
- Host specificity of parasites affected by rare and frequently sampled hosts
- Sample size correction



- Ex. (a) ectoparasites, and (b) endoparasites in freshwater fish of Canada

Structural specificity

- Ecological importance of the host for the parasite population
- Differences in abundance, intensity of infection and prevalence of parasite species



Structural specificity

- Host specificity indices
- the intensity and frequency of use of the different host species by the parasite

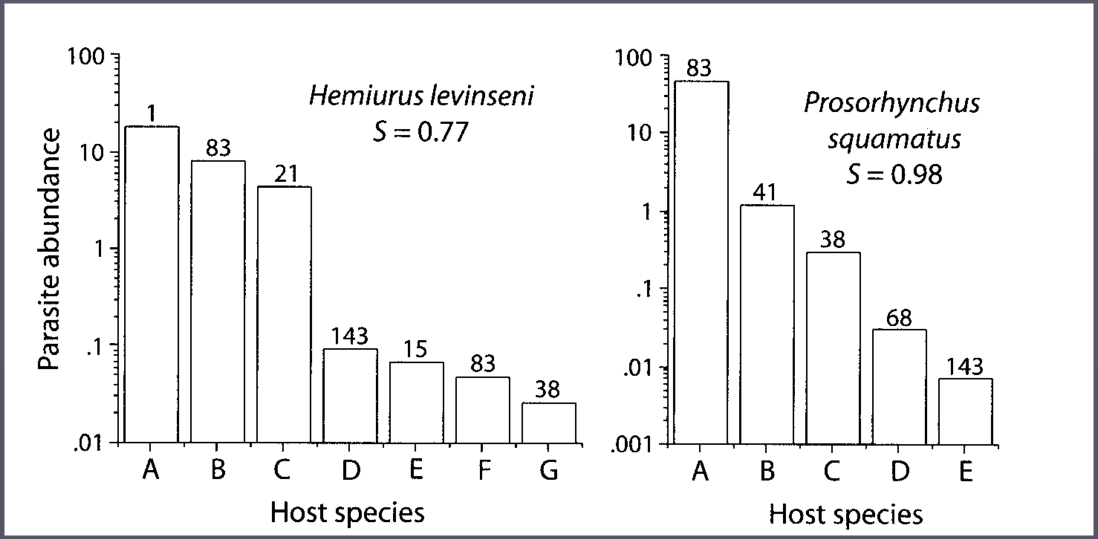
Rohde (1980)

$S = \sum(x_i/n_i h_i)/\sum(x_i/n_i)$

where x_i is the number of individuals of the parasite on i^{th} host species, n_i is the number of individuals studied of the i^{th} host species, x_i/n_i is the abundance of the parasite on the host species i, and h_i is the position of the host species i (the host species with higher parasite abundance has the position 1).

Structural specificity

- Ex. Comparison of host specificity of two digenean species parasitizing marine fishes

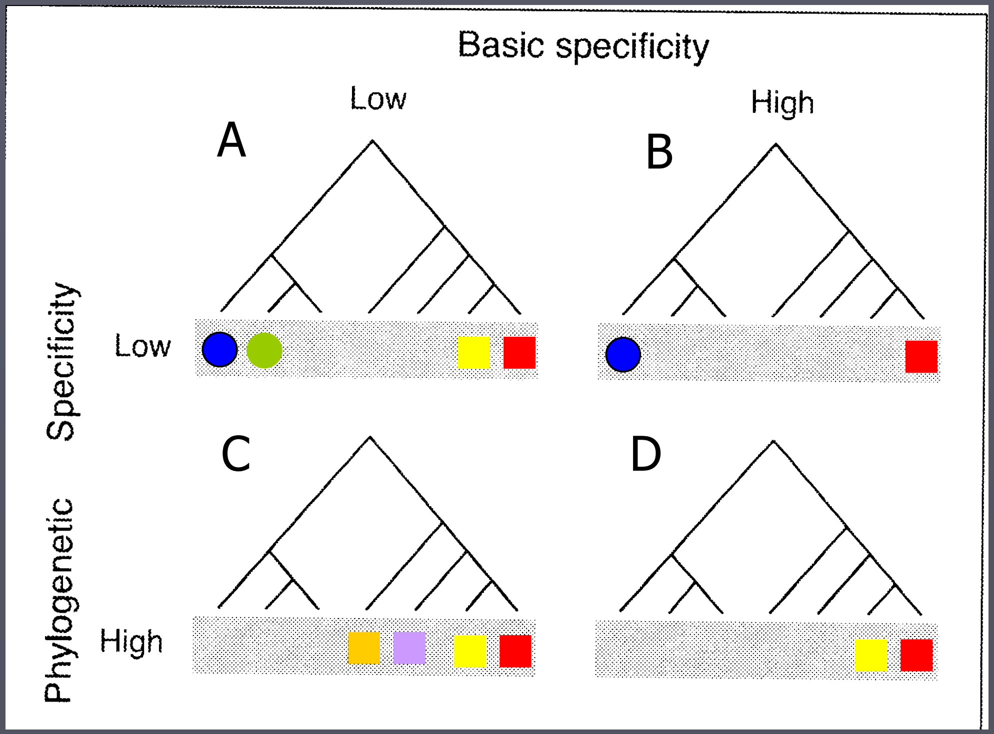


Structural specificity

- Rohde and Rohde (2008) - index removing sensitivity for the number of infected hosts
- Species diversity indices - number of species plus species abundance (e.g. Shannon index) or Levin´s niche width
- Ideal indices of structural specificity - use and availability of the host (abundance of the parasite in combination with abundance of the host in the environment)

Phylogenetic specificity

- host relatedness included in host specificity



Phylogenetic specificity

- Host specificity indices from a phylogenetic perspective

- Desdevises et al. (2002) and others
  Index based on semi-quantitative classification
  IHS = 1 - strict specialist (species specific, highly host specific)
  IHS = 2 - intermediate specialist - congeneric host species
  IHS = 3 - intermediate generalist - phylogenetically related hosts
  IHS = 4 - generalist - phylogenetically unrelated hosts

Phylogenetic specificity

- Poulin & Mouillot (2003)

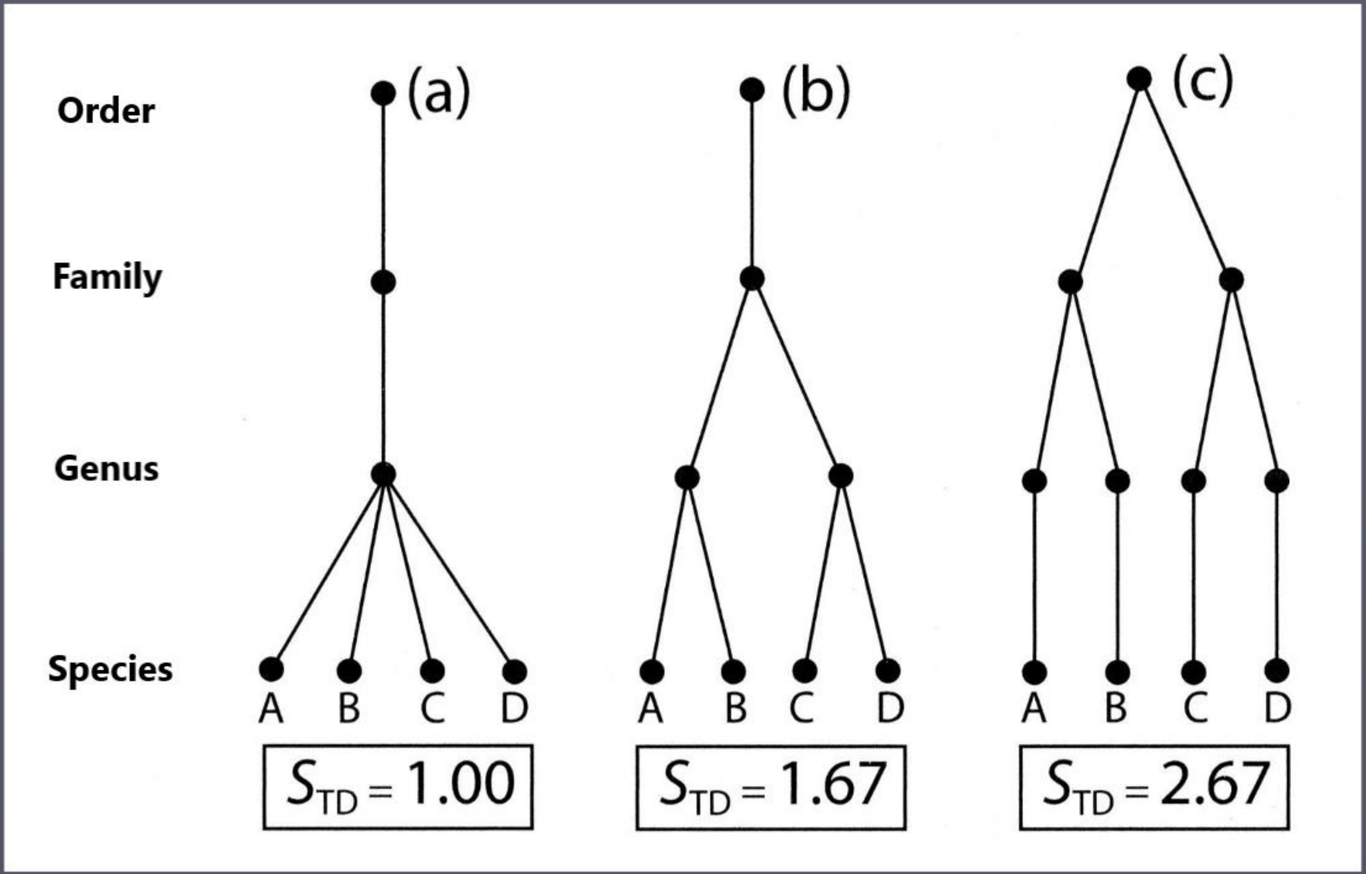
$$S_{TD} = 2 \sum\sum_{i<j} \omega_{ij} / s\,(s-1)$$

s is the number of host species used by a given species of parasite, the double sum includes the set $\{i = 1,...s;\ j = 1,...s$, where $i < j\}$ and ω_{ij} is the taxonomic difference between species i and j, or the number of taxonomic steps required to node representing a common ancestor of both species

Index of phylogenetic specificity

Comparison of host specificity of 3 species of parasites

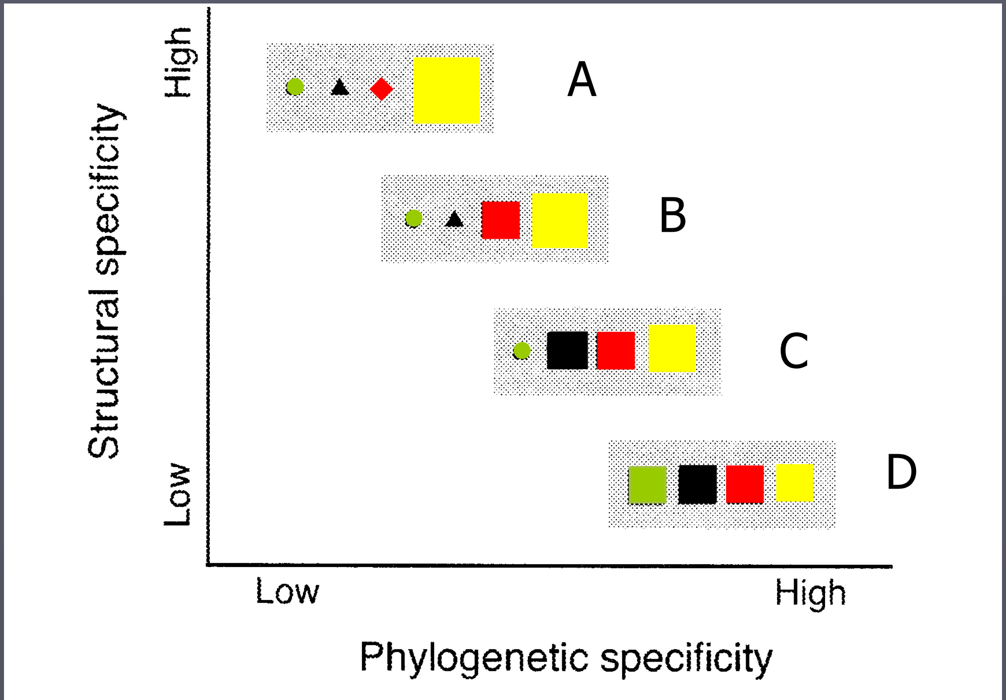
Host species



Minimum IS = 1 – host-specific parasite species

Host specificity

- Expressed using basic, structural and phylogenetic components



Hypothetical relationship between structural and phylogenetic components of host specificity. Abundance is affected by physiological or other factors.

Phylostructural specificity

- It combines evolutionary and ecological aspects of HS
- Poulin & Mouillot (2003)

index of HS – phylogenetic distance of host species plus parasite prevalence in different host species

Prevalence weight factor 1 = 100% in two host species, 0 - very low

$$S_{TD}* = \sum\sum_{i<j} \omega_{ij} (p_i p_j) / \sum\sum_{i<j} (p_i p_j)$$

ω_{ij} is the taxonomic difference between species *i* and *j* or the number of taxonomic steps required to node of a common ancestor of both species, p_i a p_j are the prevalence of the parasite in host species *i* and *j*.

Phylostructural specificity

- 3 types of parasites
- Parasite "A" achieves high abundance in two congeneric host species and low abundance in two other species from different genera
- Parasite "B" achieves the same abundance in 4 different (phylogenetically distant) species
- Parasite "C" achieves higher abundance in two host species from different taxa and lower in the other two also from different taxa

Which one is more specific?

Phylostructural specificity index

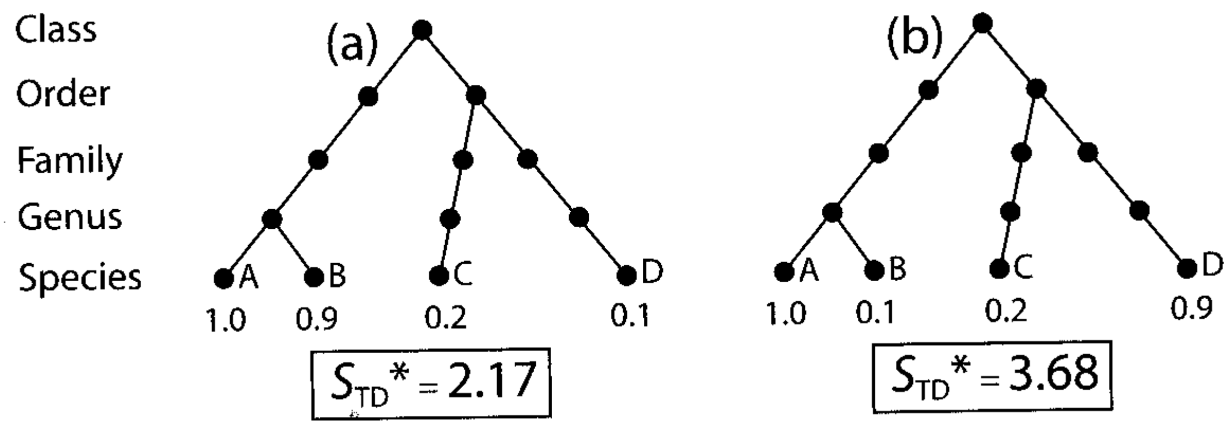


Figure 3.4 Taxonomic structure of the sets of hosts for two hypothetical parasites, with prevalence in each host indicated below. There are four host species, A to D, in each example. The taxonomic tree of host species is the same in both cases, as are the prevalence values; however, the distribution of prevalence values among host species differs between the two examples. The index $S_{TD}*$ achieves a higher value in (b) than (a) because of the greater taxonomic distance among host species with high prevalence. (Modified from Poulin and Mouillot 2005)

Host specificity in geographical space

- Host communities with different composition and relative density in different localities

- Consistency of the parasite to use of the host species in geographical space

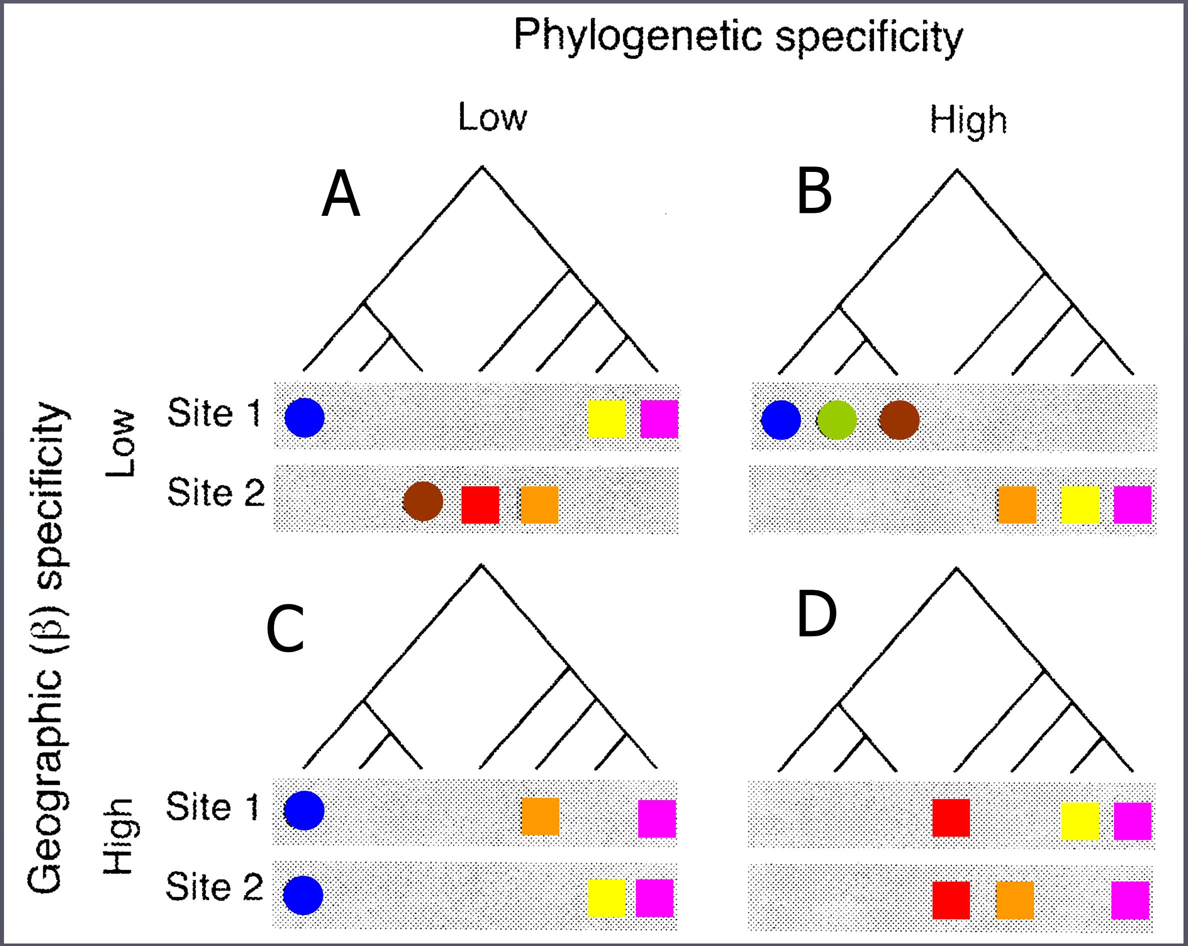
- Ex. Host specificity of parasite A vs. parasite B

parasite A - same host species in 2 localities, same abundance in 2 localities, phylogenetically related host species

parasite B – different host species in 2 localities, but same abundance in 2 localities, phylogenetically related host species

which is more specific?

Phylobetaspecificity - a combination of phylogenetic and geographical specificity



α-specificity and β-specificity

Host specificity for a given site (locality) – α-specificity

in all localities – β-specificity

(analogy to α-diversity and β-diversity)

!!! The problem of defining host specificity

local level - species-specific parasite (specialist)

regional level - non-specific parasite (generalist)

Definition of host specificity

- Local level: absence of a certain suitable host species, low sampling size
- Global level: erroneous taxonomic determination, problem of random hosts

- For some generalist parasites:

global level: a wide range of host species

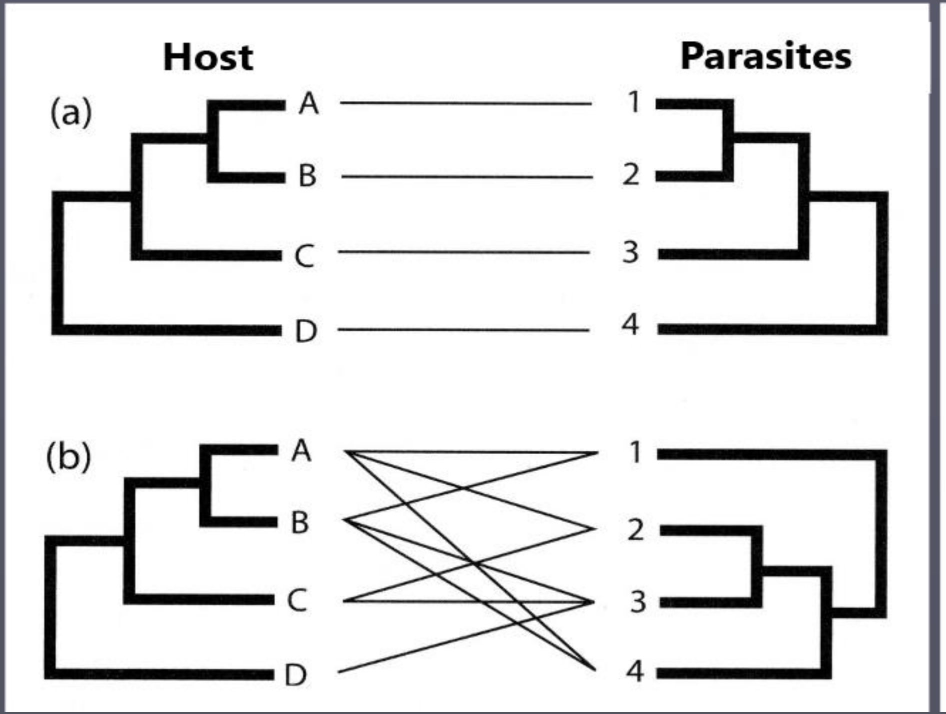
preferred (common) host species - abundance of the parasites is the highest to maintain the parasite population

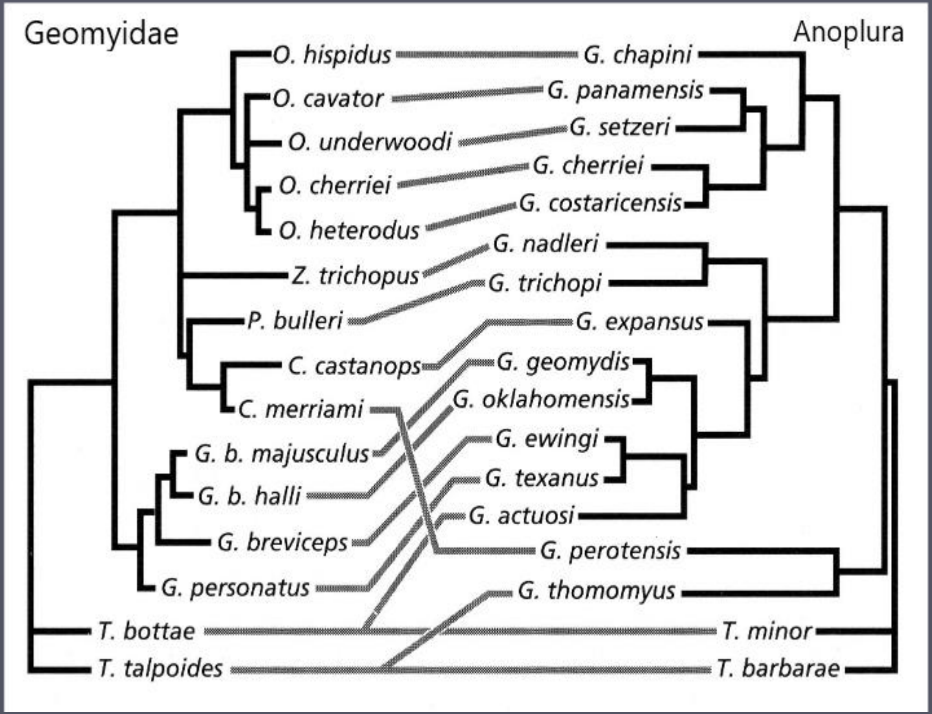
additional host species - the abundance of the parasite is low

local level: preferred host species only

Macroevolutionary processes - history of host-parasitic associations

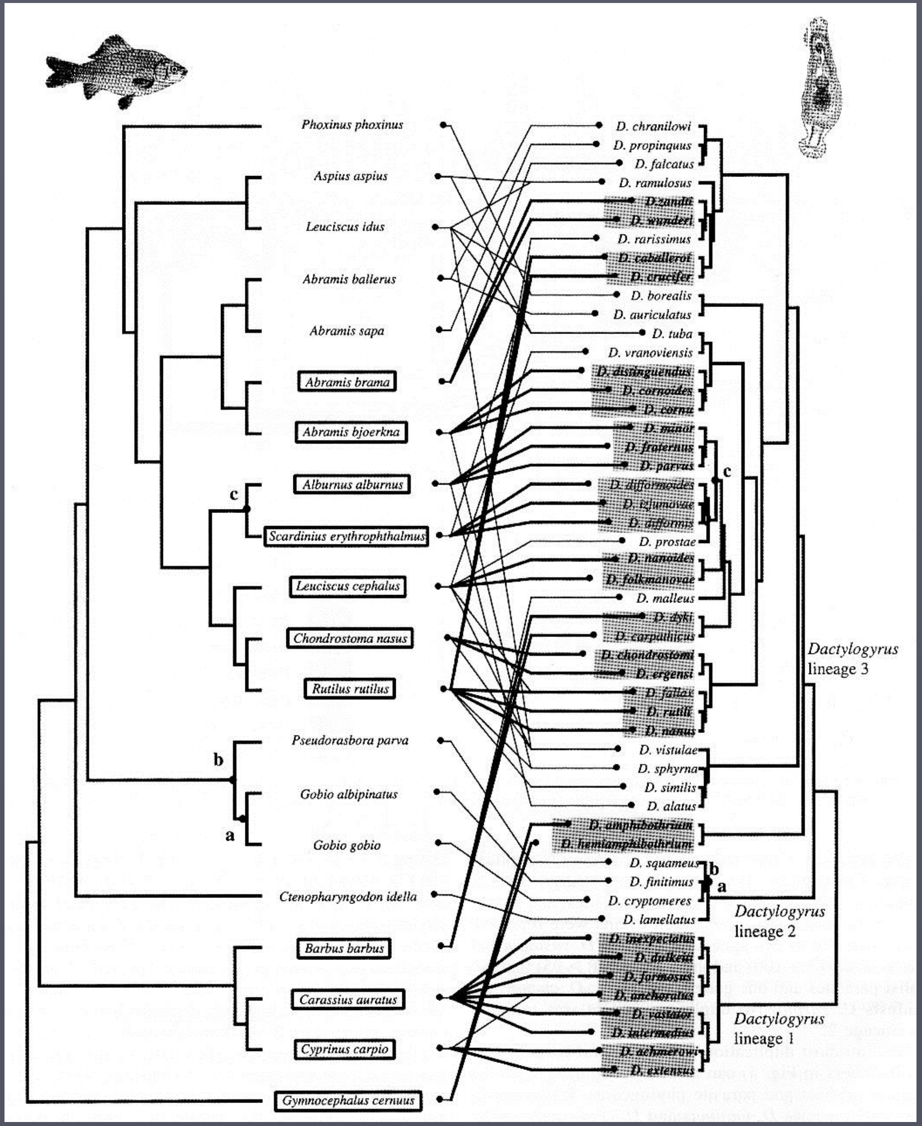
- Cospeciaton between hosts and host-specific parasites - identical phylogenetic reconstruction of hosts and parasites (Fahrenholz rule)





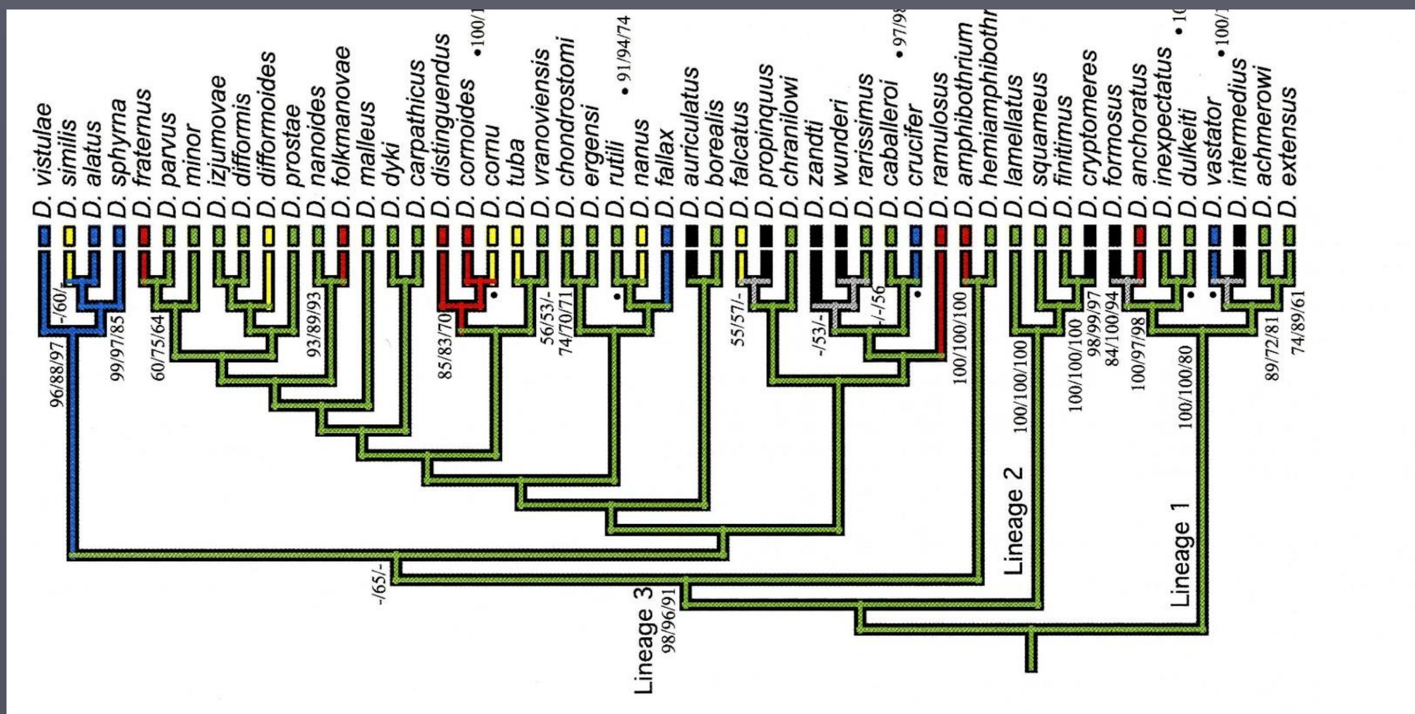
Macroevolutionary processes - history of host-parasitic associations

- **Host specificity does not have to reflect co-speciation** – highly specific parasite-host systems with coevolution form intra-host speciation a "host switching"



Evolution of host specificity

- A specialist evolves from a generalist, and many specialists arise from other specialists
- Evolution leads to host preference → rapid coevolution between specialists and the immune system
- !! Specialist ancestral character, generalist derived



Microevolutionary processes

- Physiological and ecological factors of the host and parasites
- Natural selection favors certain changes in host specificity - increasing or decreasing?
- trade-off between the ability to use a lot of hosts and the average parasite fitness on/in those hosts
- Trade off documented in metazoan parasites of freshwater fish in North America
- The opposite relationship is also documented (fleas parasitizing small mammals)
- no relationship (helminths parasitizing birds)

Microevolutionary processes

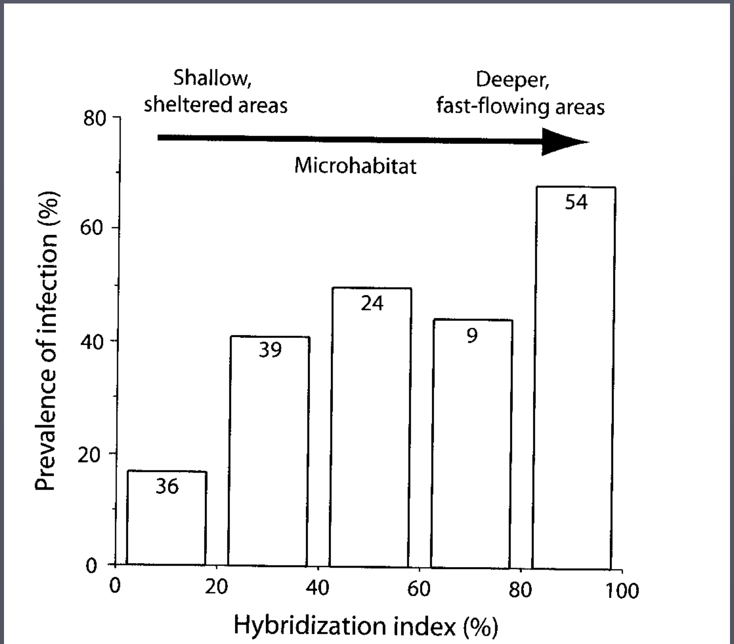
- Existence of a trade-off linked to the costs associated with adaptation to multiple host species

- Sometimes small costs, for example, the nematode *Howardula aoronymphium* parasitizing several species of *Drosophila*

  experiment 25 generations - selection for one host species, parasite still retains the ability to parasitize on different host species

Microevolutionary processes

- Host specificity is determined by the possibilities for colonization and the availability of a suitable host
- Ex. Host hybridization - a genetic and ecological bridge between host species for parasites

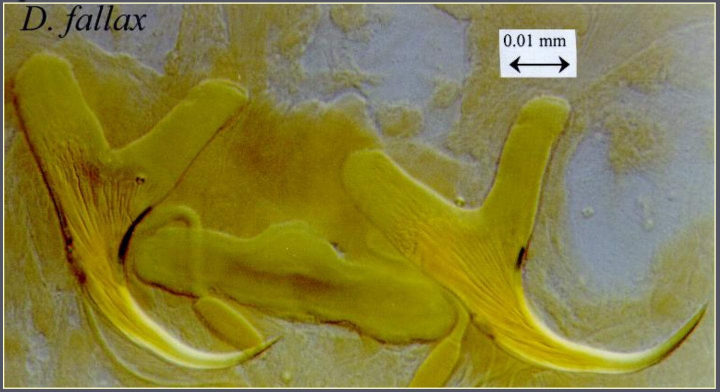


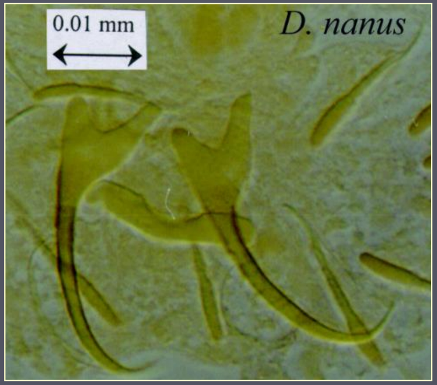
Ex. Prevalence of infection *Paradiplozoon homoin* as a function of hybridization between *Barbus meridionalis* and *B. barbus*

Microevolutionary processes - adaptation

- Host specificity is associated with adaptation and specialization
- Evolution of host specificity with evolution of morphological adaptation (e.g. morphology of parasite attachment organs)
- Possible biochemical interactions

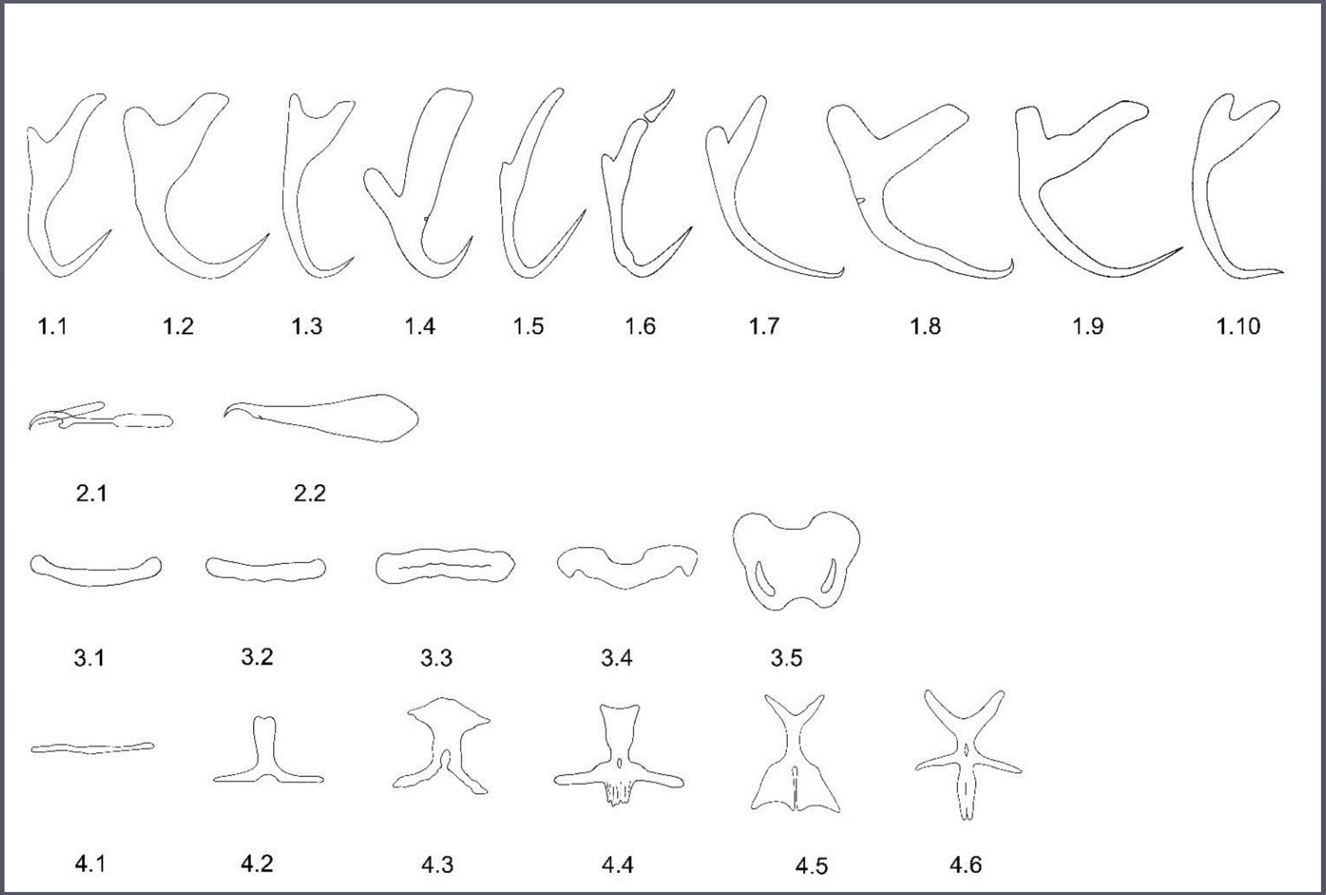
- !!! Morphological adaptation in generalists – e.g. robust hooks in *Dactylogyrus* (Monogenea) - necessity of adaptation to more hosts?



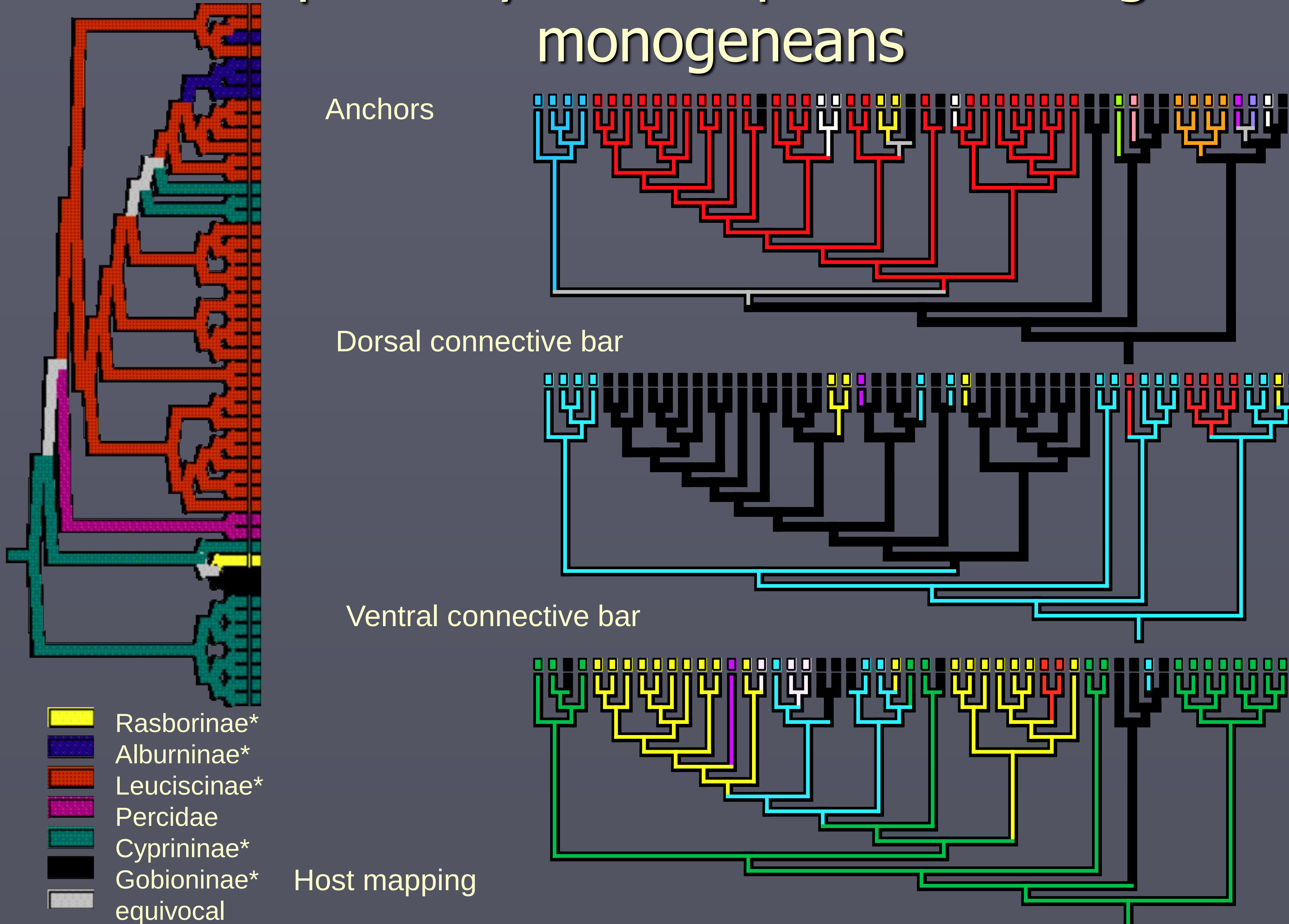


Host specificity and adaptation in congeneric monogeneans

- Ex. 51 species of the genus *Dactylogyrus* from 20 species of freshwater fish

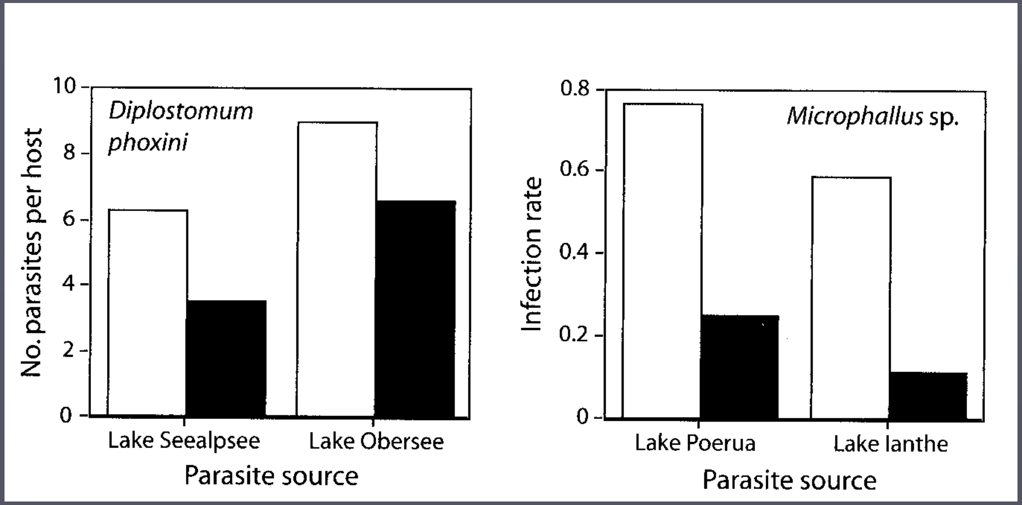


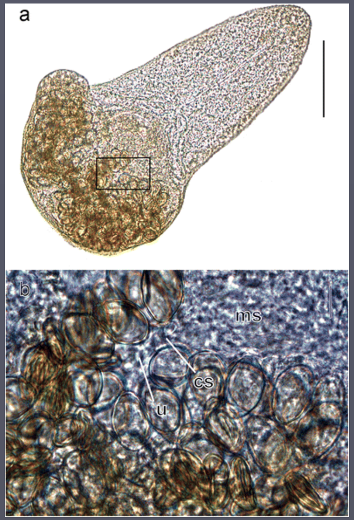
Host specificity and adaptation in congeneric monogeneans



Microevolutionary processes - adaptation

- Selection for higher specificity at the population level
- Adaptation to the local host population

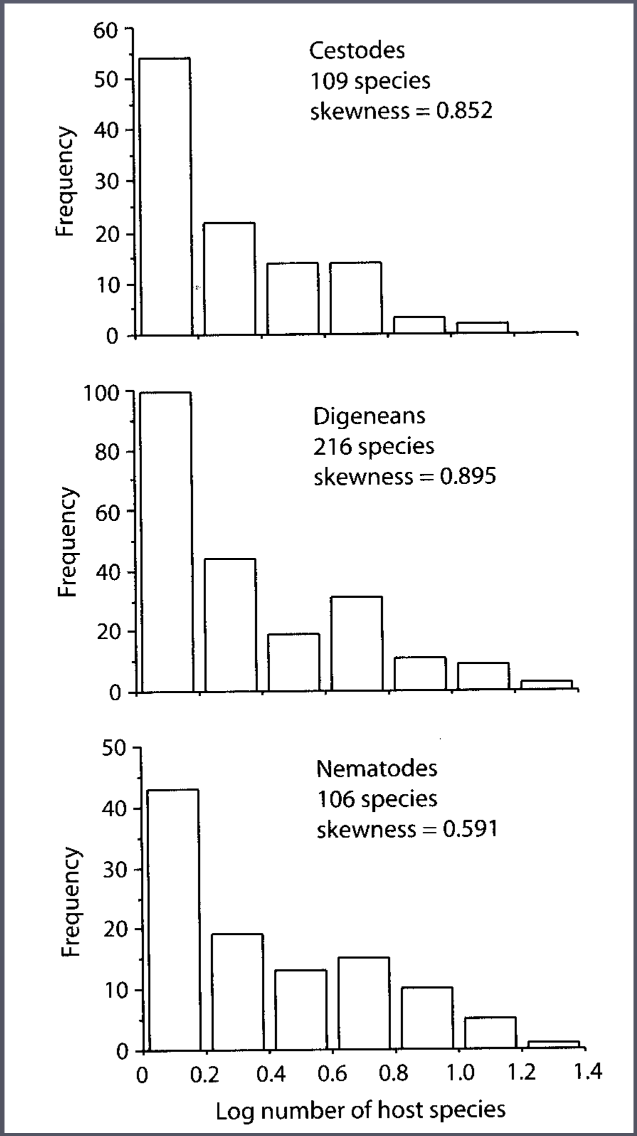




Ex. *Diplostomum phoxini* (Digenea) in fish in two Swiss lakes, *Microphallus sp.* at the intermediate host of a snail from two lakes in New Zealand

Observed patterns of host specificity

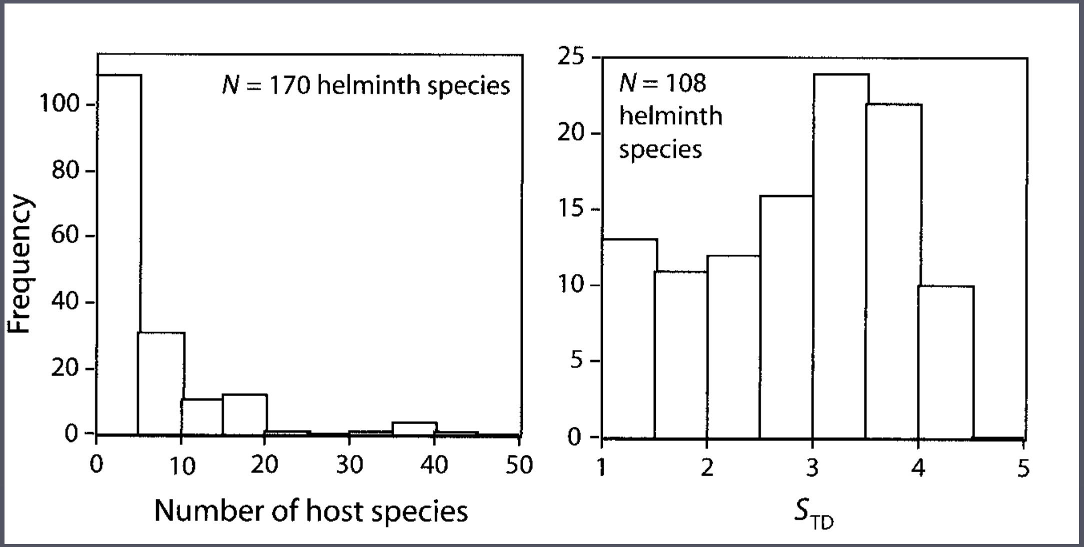
- Species-rich parasite taxa - most parasites tend to be host-specific
- Distribution of host specificity within taxa, distribution is skewed
- Ex. Frequency distributions of number of known host species for Cestoda, Digenea and Nematoda in birds



Observed patterns of host specificity

- Frequency distribution of two measures of host specificity - number of host species and index of host specificity

  Ex. Helmints of freshwater fish of Canada



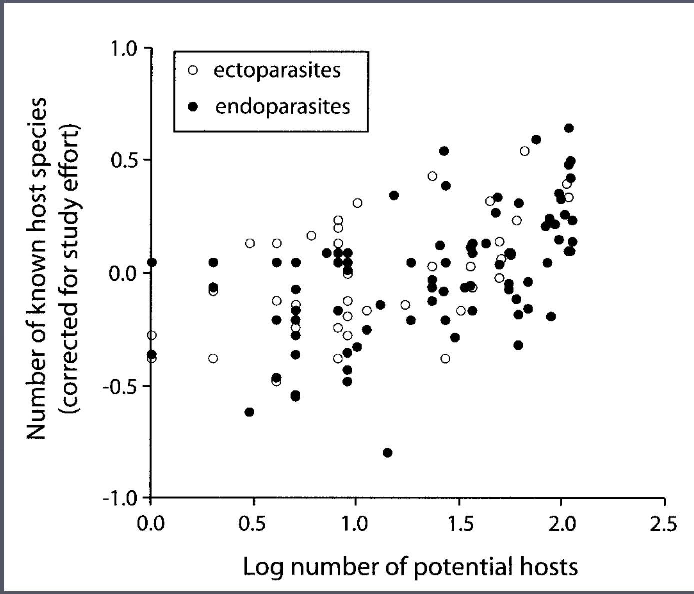
Observed patterns of host specificity

- Parasitic groups differ in their host specificity
- Parasites with a simple life cycle - more host-specific
- Parasites with a complex life cycle - higher specificity for intermediate hosts than for the final host

- Host specificity of helminths
- Ectoparasitic Monogenea - highly specific, more than half on one host species
- Endoparasitic helminths - higher range of DH species but strict specificity of miracidia to IH (snails)

Observed patterns of host specificity

- Increasing the number of host species due to host switching processes
- The alternative host species shows some physiological or ecological similarity

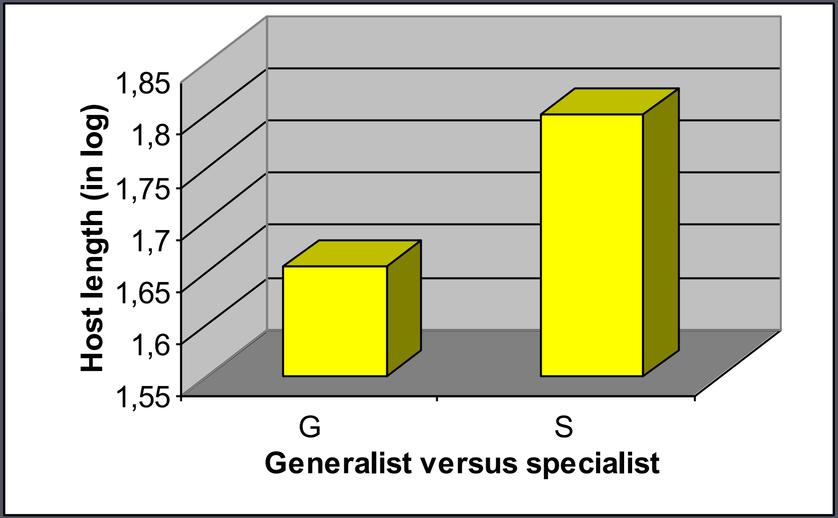


- Ex. Relationship between the number of known host species and the number of potential host species for ectoparasites and endoparasites of freshwater fish in Canada

Determinants of host specificity

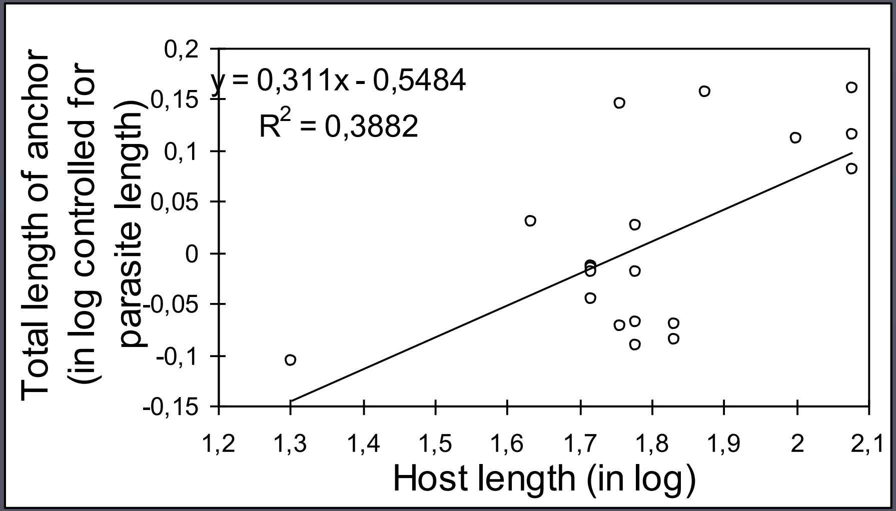
- **Specialization on predictable sources**
- specialization on stable sources minimizes the risk of extinction
- - stable host for parasites = large, long-lived, with high density, at the top of the food chain → higher fecundity and survival of parasites

Ex. 44 species of the genus *Dactylogyrus* (Monogenea) on 19 cyprinid species

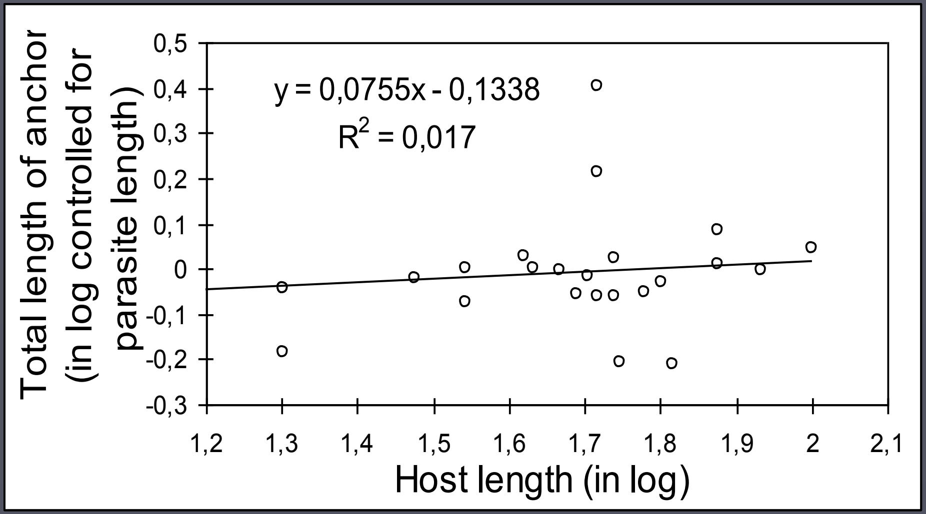


Determinants of host specificity

- Ex. *Dactylogyrus* (Monogenea) specialists living on longer hosts have longer attachment hooks = optimization of morphological adaptation



Specialists



Generalists

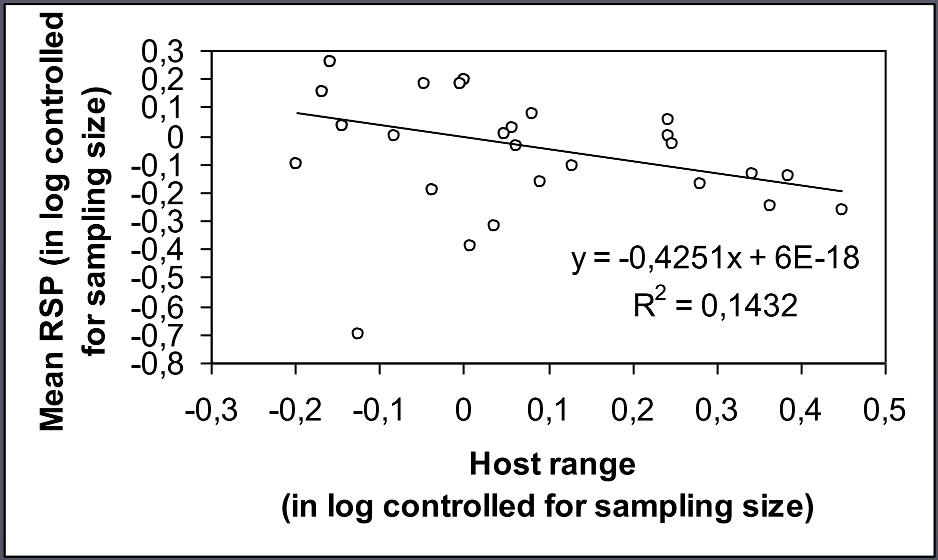
Ecological specialization

- Species that use more resources show higher local abundance and are more widespread in nature than species that use a narrow range of resources (Brown, 1984)

- Host-parasitic systems: generalists use more hosts → higher abundance and prevalence (measure of distribution within hosts) than specialists

Specializing on enemy-free space

- Species specialization in the absence of potential competitors (Jeffries & Lawton, 1984) = specialists occur in species-poor communities



Not confirmed for parasites