BIG4
Biosystematics, Informatics, Genomics

BIG4 field workshop

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What is a species ?

Martin FIKÁČEK

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What is a species?

"No one definition of species has as yet satisfied all naturalists; yet, every naturalist knows vaguely what he means when he speaks of a species"

Darwin (1859) The origin of species…

Table 19.1 Species concepts and standardized abbreviations

1. Agamospecies (ASC)
2. Biological (BSC)
3. Cohesion (CSC)
4. Cladistic (ClSC)
5. Composite (CpSC)
6. Ecological (EcSC)
7. Evolutionary Significant Unit (ESU)
8. Evolutionary (ESC)
9. Genealogical Concordance (GCC)
10. Genetic (GSC)
11. Genotypic Cluster Definition (GCD)
12. Hennigian (HSC)
13. Internodal (ISC)
14. Morphological (MSC)
15. Non-dimensional (NDSC)
16. Phenetic (PhSC)
17. Phylogenetic (PSC)
    1. Diagnosable Version (PSC_1)
    2. Monophyly Version (PSC_2)
    3. Diagnosable and Monophyly Version (PSC_3)
18. Polythetic (PtSC)
19. Recognition (RSC)
20. Reproductive Competition (RCC)
21. Successional (SSC)
22. Taxonomic (TSC)

List of different species concepts according to Mayden (1997)

Morphological species (morphospecies)

"Species are varieties with no or few morphological intermediates" Darwin 1859

Two morphological forms without intermediates

= two species

Continual row of intermediates between forms **= one species**

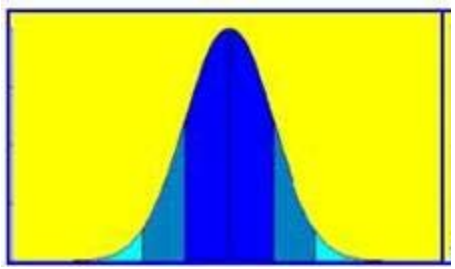
Morphological species (morphospecies)

Two loci influencing:

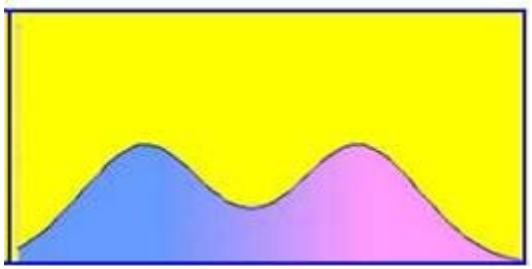
One population
alels in both loci in H-W equilibrium, without linkage)

Two isolated populations
(alels without H-W equilibrium, with linkage)

Quantitative character (in an additive way)

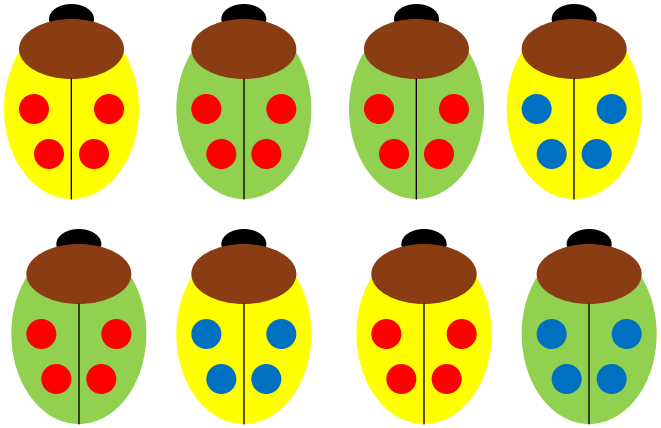


One peak, normal distribution

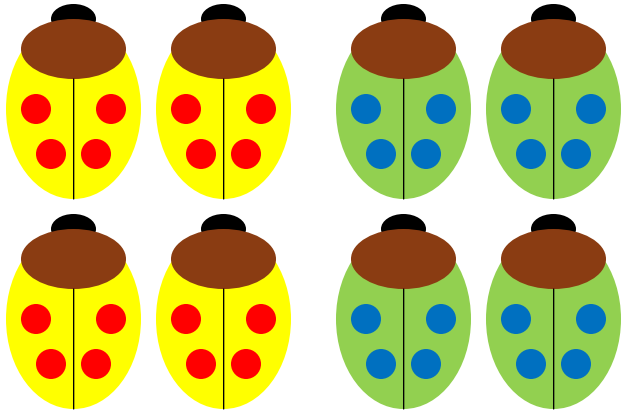


bimodal distribution (two peaks)

Two qualitative characters

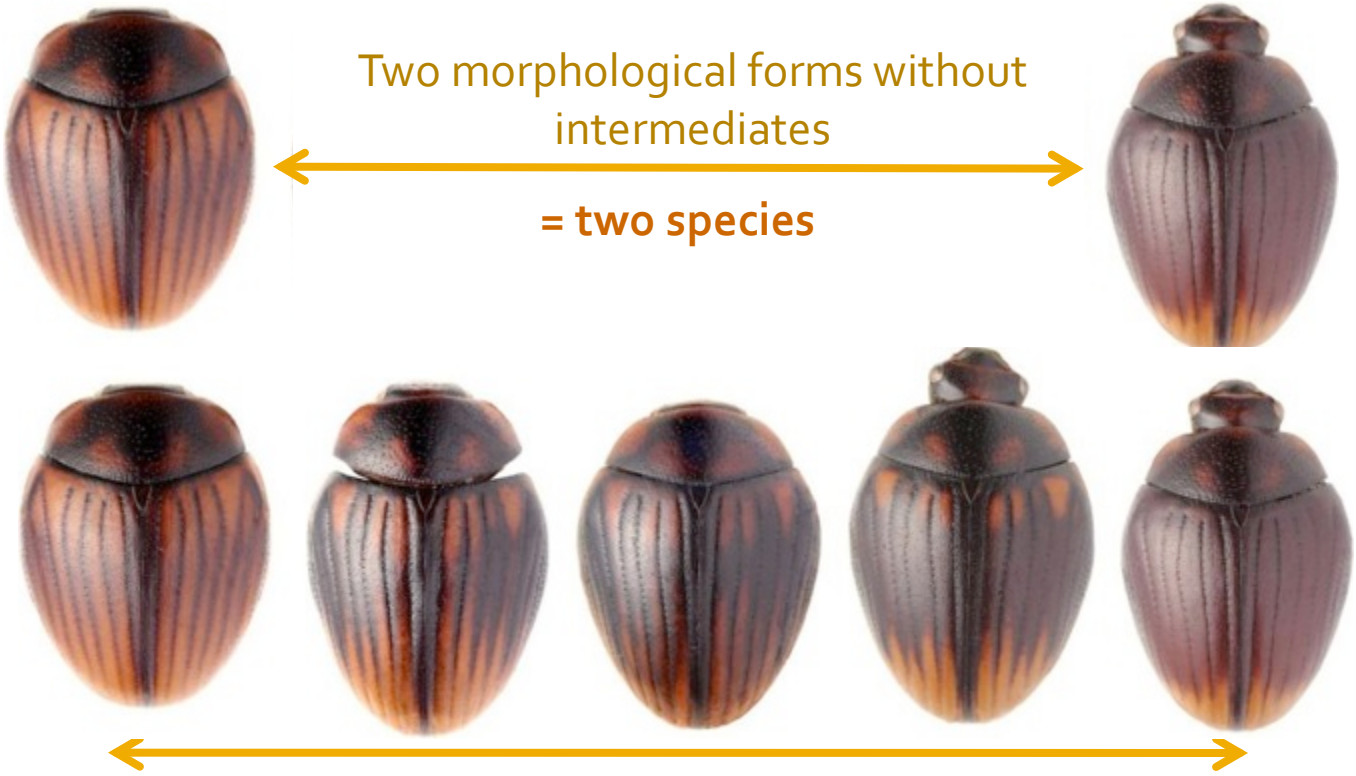


Without strong correlation



With strong correlation

Morphological species (morphospecies)



Morphological difference is understood as a proxy indicating the isolation of populations

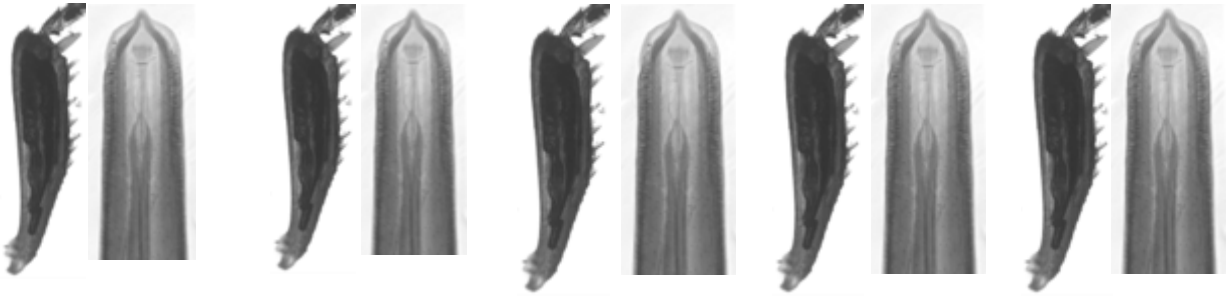
Looking for "morphological gaps" and correlations of characters

Morphological species (morphospecies)

Problems:

Some characters are more important to distinguish species than others (usually based on the experience of a taxonomist)

Coloration: unreliable characters (varies within species)



Shape of profemur and genitalia: reliable character (constant within species)

Selection of reliable and unrealibale characters is very subjective!

Morphological species (morphospecies)

Problems:

Some characters are more important to distinguish species than others (usually based on the experience of a taxonomist)

Cannot distinguish species without morphological differences (because does not use other information that morphology)

European *Cimex on bats*:
In Europe there are probably two species, but the cannot be distinguished by morphological characters

Morphological species (morphospecies)

Problems:

- **Some characters are more important to distinguish species than others** (usually based on the experience of a taxonomist)
- **Cannot distinguish species without morphological differences** (because does not use other information that morphology)
- **Has problems with sexual dimorphism and intraspecific polymorphism**

Morphological species (morphospecies)

Strepsiptera

Hymenoptera: Embolemidae

Has problems with sexual dimorphism and intraspecific polymorphism

Morphological species ?

How many species is this?

Morphological species ?

One or two species?

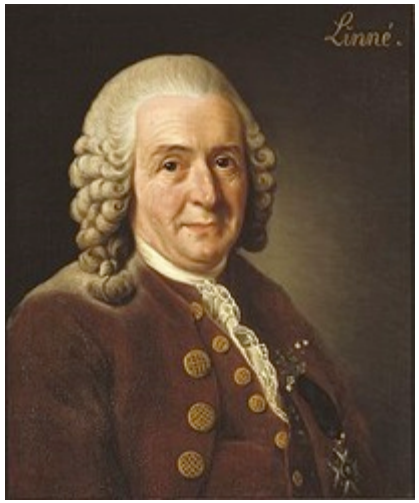
Morphological species ?

One or two species?

Polyommatus icarus (Rottemburg, 1775)

Lucanus cervus Linnaeus, 1758

Morphological species (morphospecies)



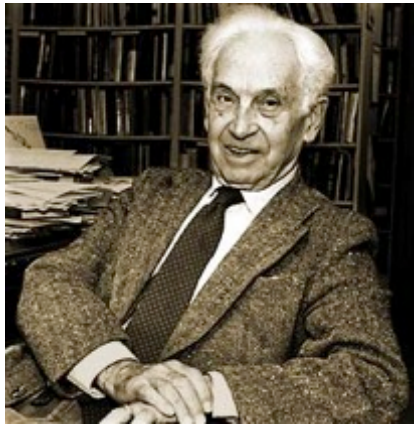
Already the old authors used the morphological species concept only in case no other information were available.

If they had more information than morphology, they adapted their species concepts accordingly.

Morphological species concept defines where to put the border between species in case we only have information about morphology

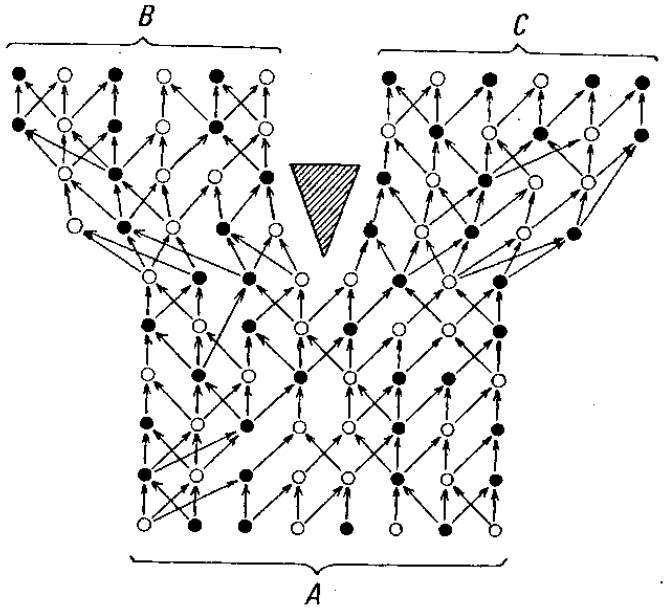
It defines how to recognized species from each other, but does not say WHAT is a species!

Biological species



"A species is a group of interbreeding natural populations that is reproductively isolated from other such groups"

Mayr & Ashlock (1991)



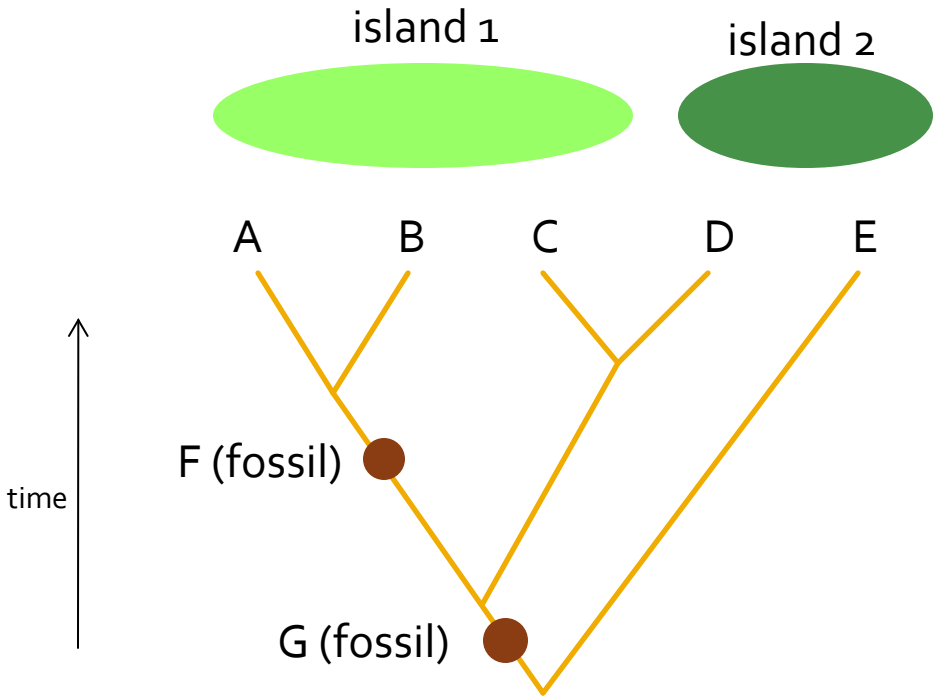
This means that:

- A species includes individuals which may interbreed and reproduce (and get fertile offsprings)
- Species are "divided" from each other by isolation barriers preventing their interbreeding and reproduction

Biological species

Problems:

Reproductive isolation as a criterion makes sense only in recent sexual species which ranges do overlap.



Biological species

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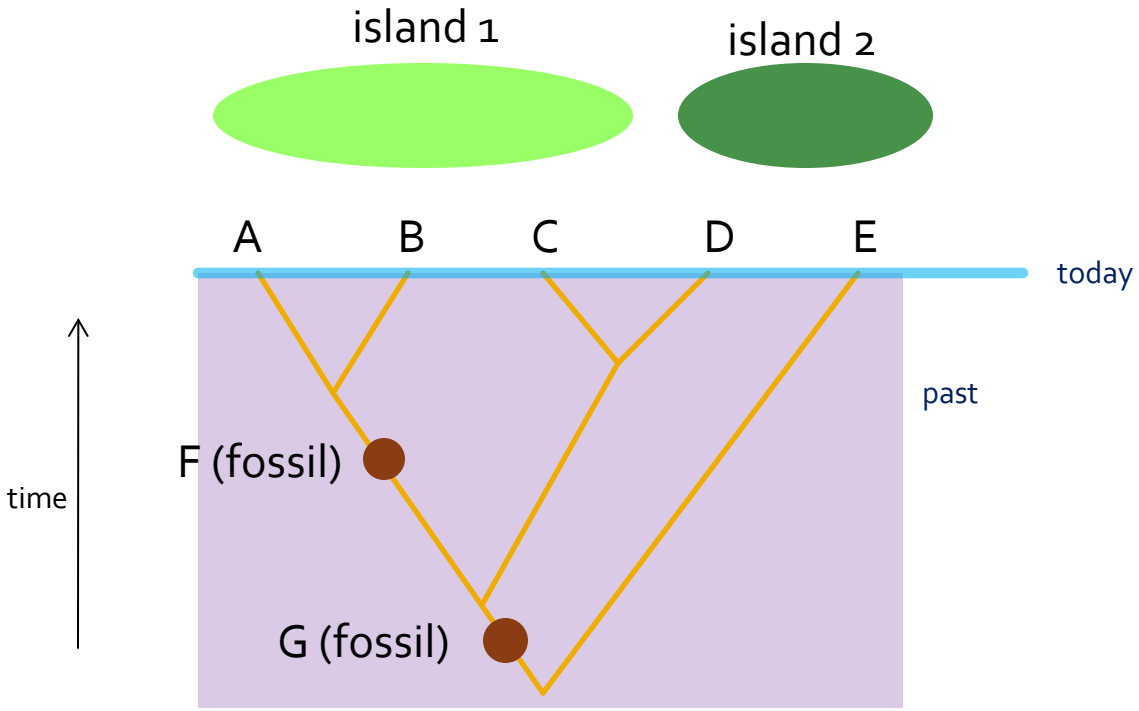

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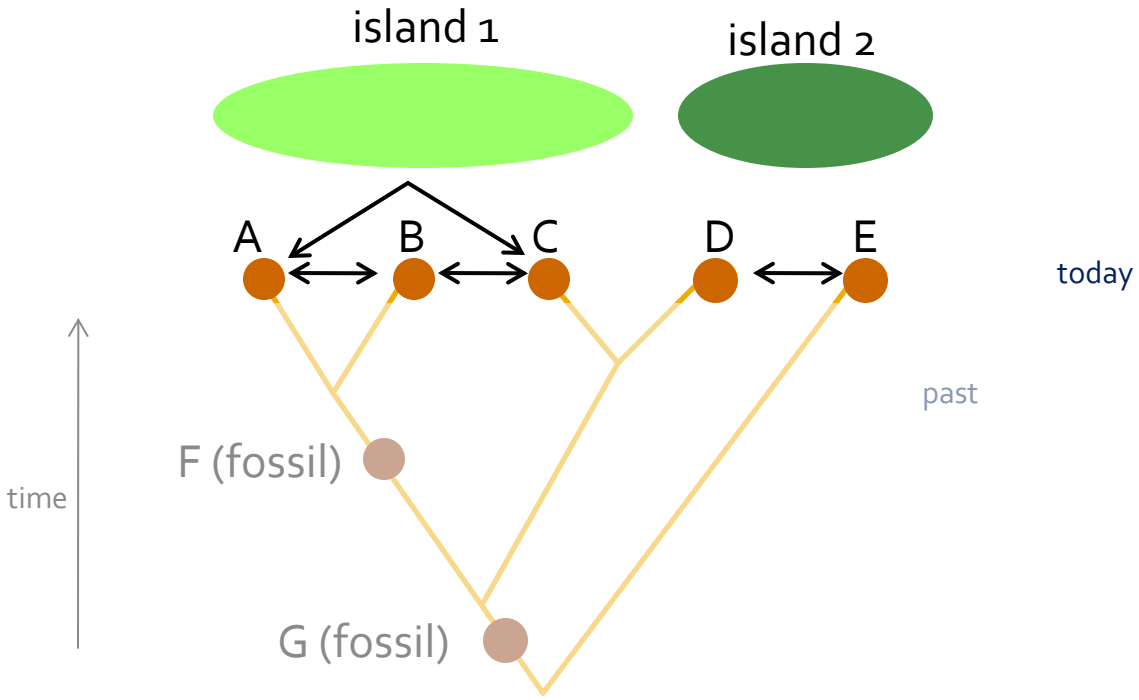
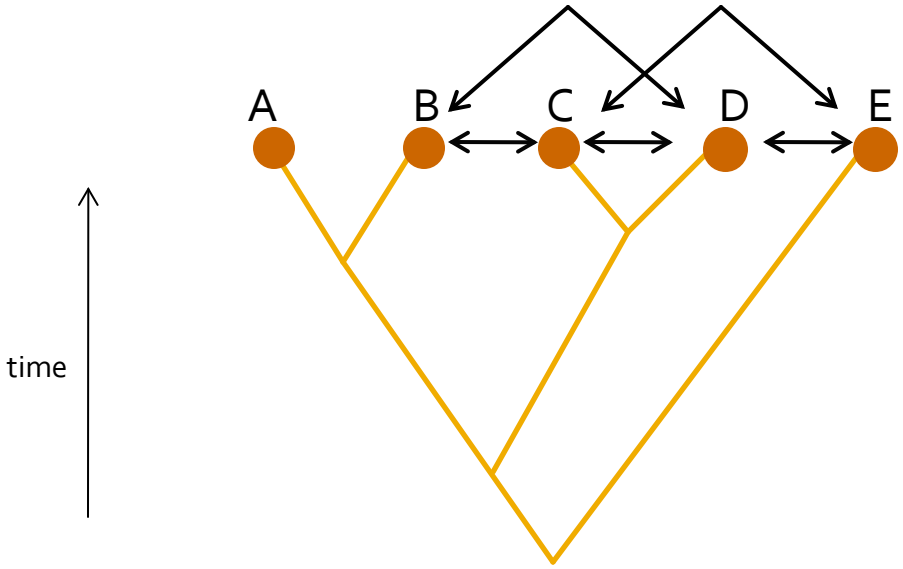


Biological species

Problems:

- **Reproductive isolation as a criterion makes sense only in recent sexual species which ranges do overlap.**
- **Focuses on reproductive isolation, not monophyly of the species**



Biological species

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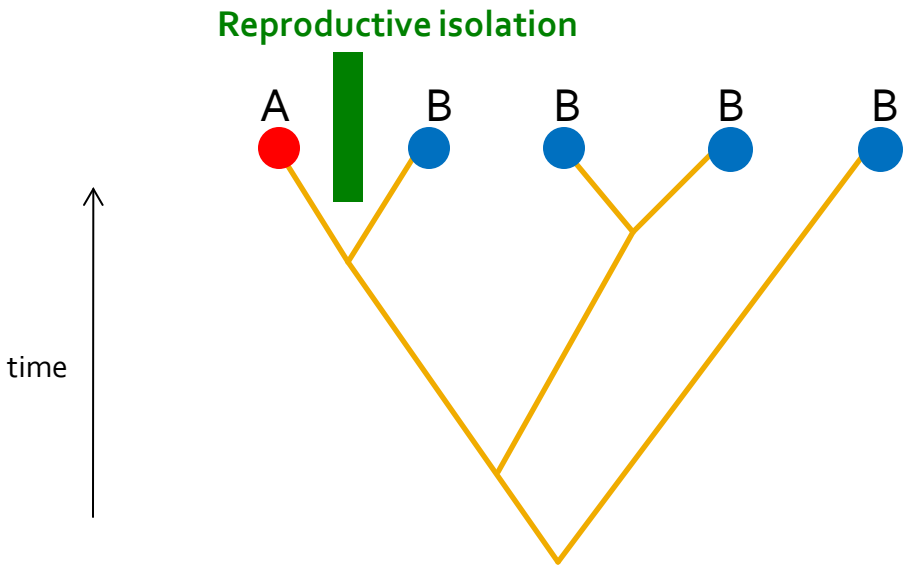
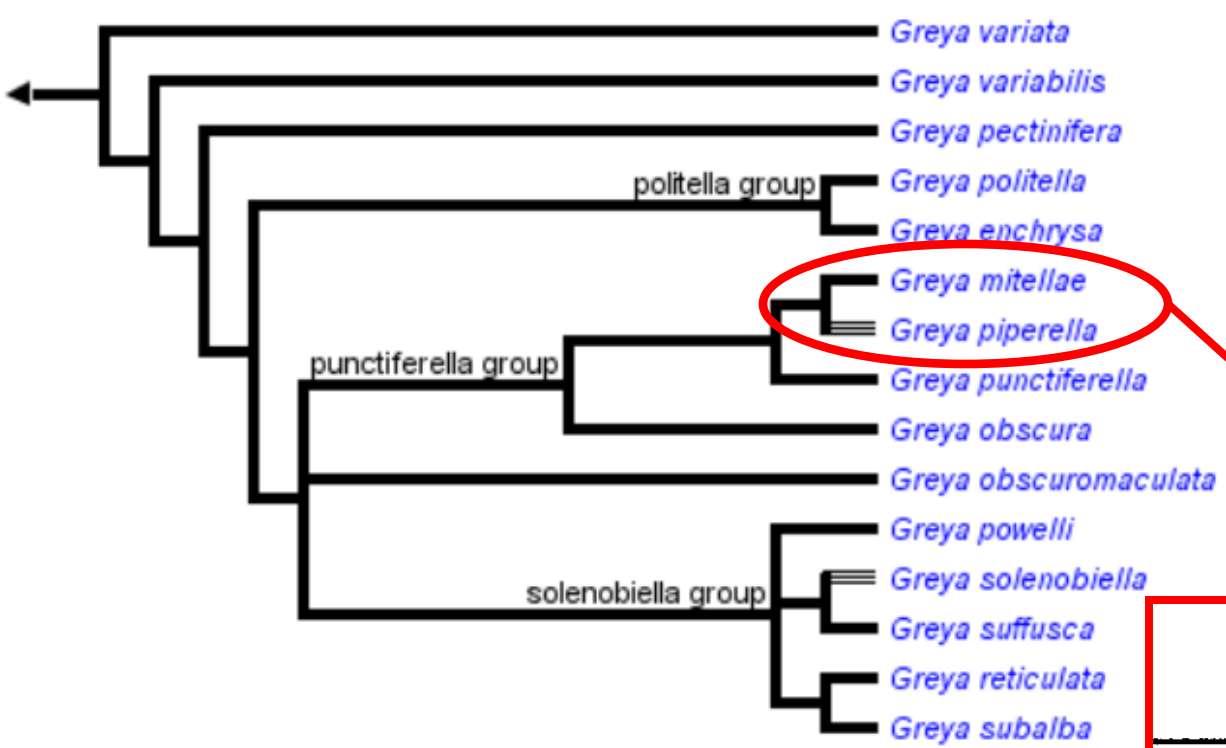
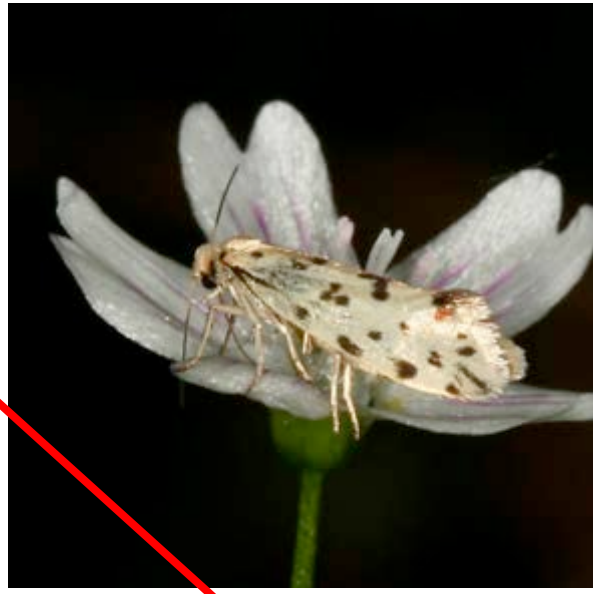
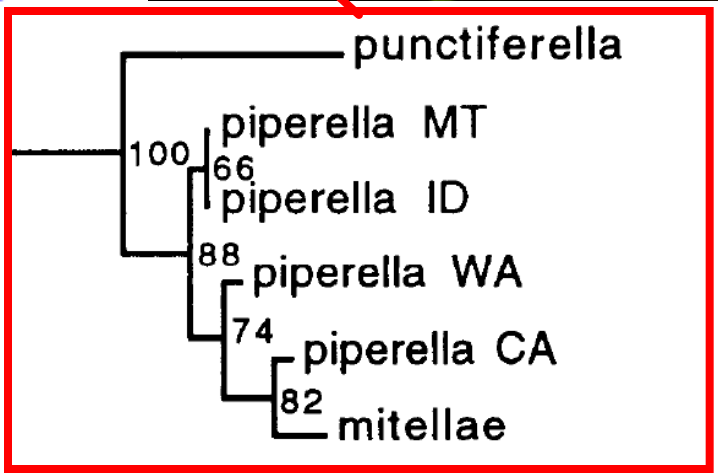


Biological species







Greya piperella a *G. mitellae* differ in morphology and use different host plant

Biological species

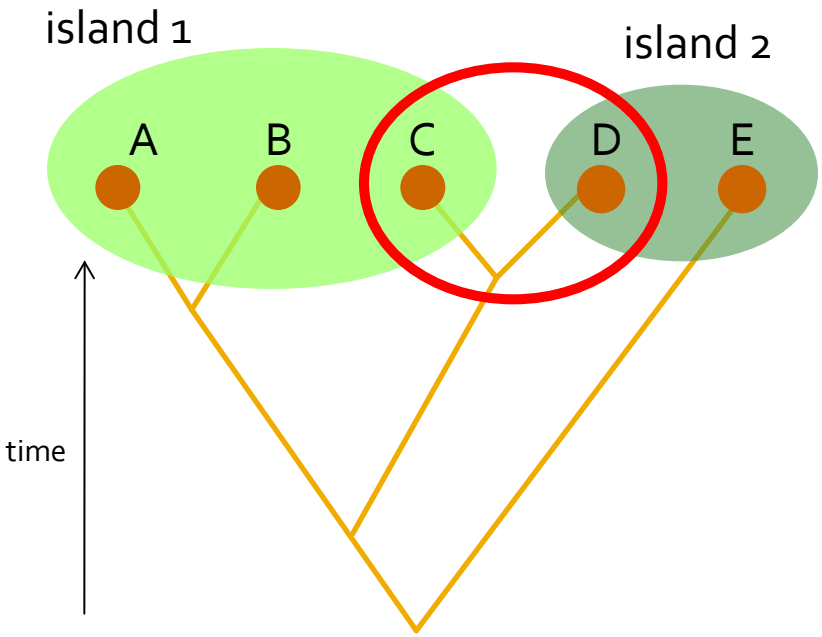
Problems:

- Reproductive isolation as a criterion makes sense only in recent sexual species which ranges do overlap.
- Focuses on reproductive isolation, not monophyly of the species
- It is not easy to test the reproductive isolation and viability of offstrings (laboratory rearings!).
- Interspecific hybridisation is possible and in some cases probably rather frequent

Phylogenetic species

The species is the smallest diagnosable cluster of individual organisms within which there is a parental pattern of ancestry and descent.

i.e. the species has to be monophyletic and recognizable from other species



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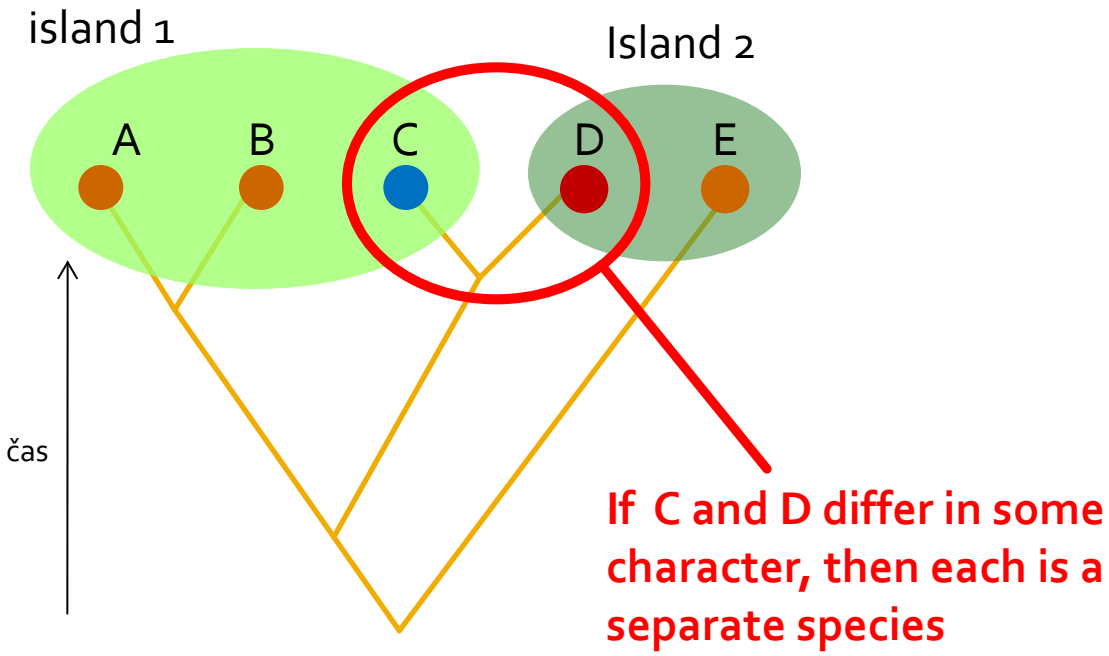

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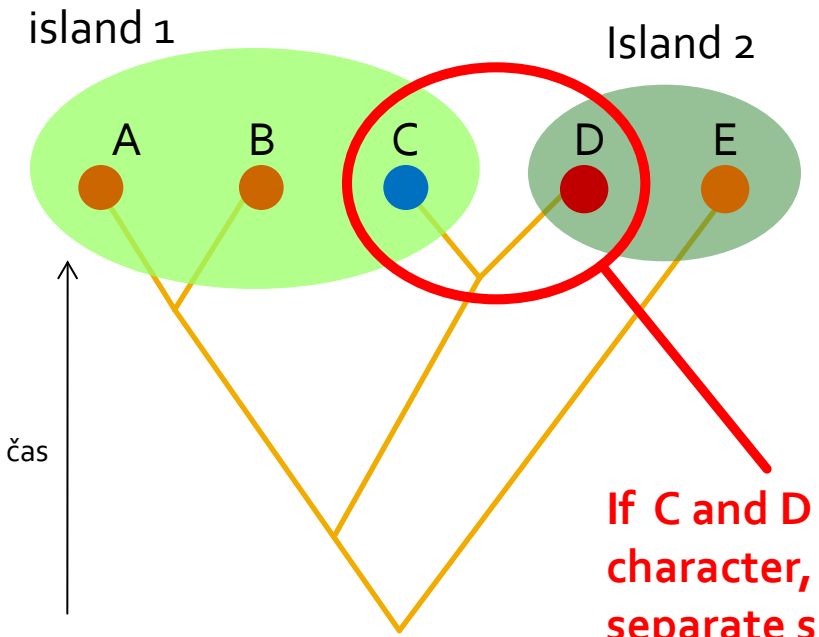
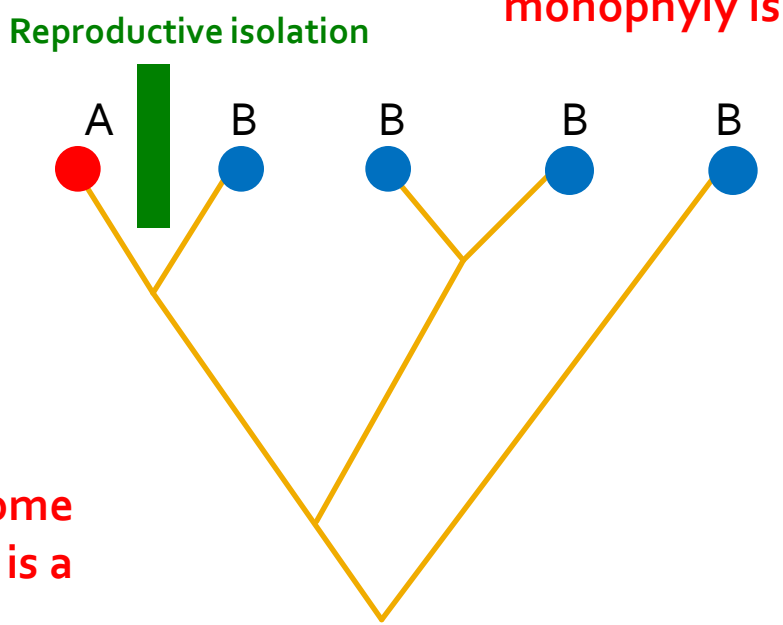


If C and D differ in some character, then each is a separate species

Reproductive isolation is not important, monophyly is



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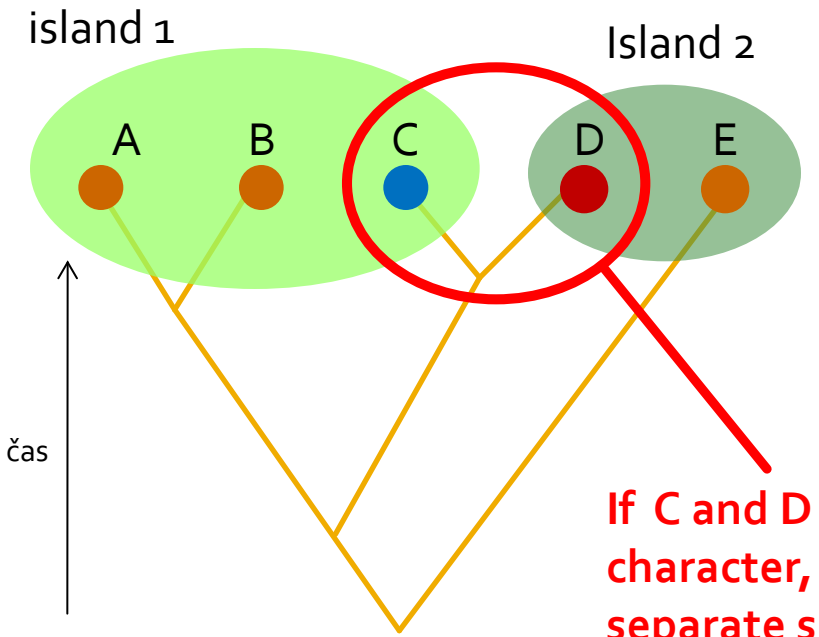

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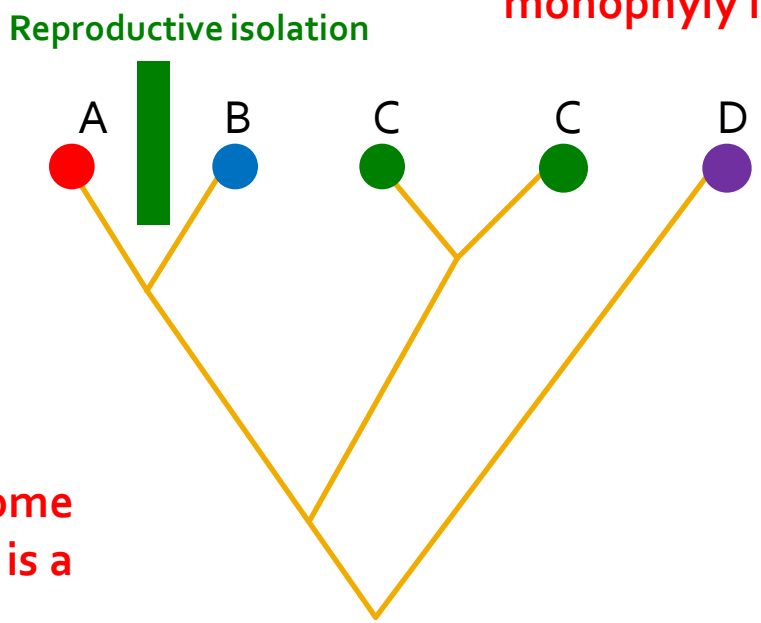

Phylogenetic species

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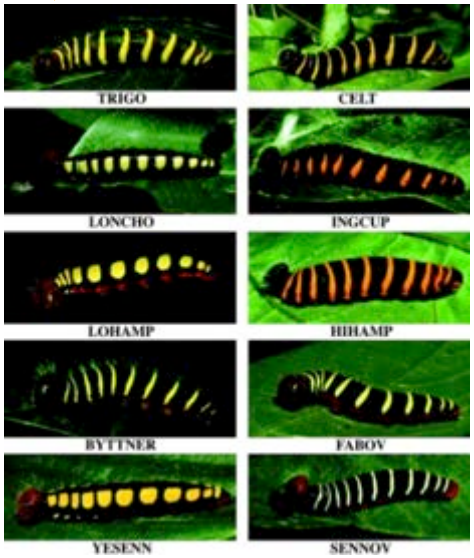
i.e. the species has to be monophyletic and recognizable from other species

Any character may be used for diagnosing the species



Astraptes favilla sp. nov.

Type locality. Costa Rica, Alajuela Prov. Area de Conservacion Guanacaste, Sector Del Oro, Puente Mena, 11.04562° N, 85.45742° W, 280 m.

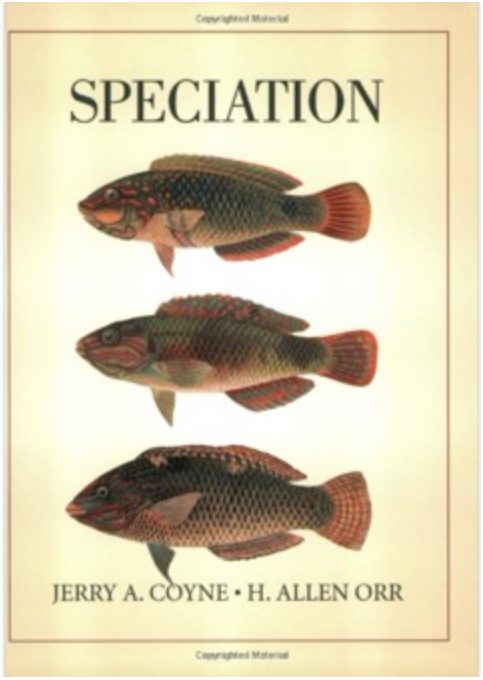
Diagnosis. The species may be differentiated from other members of the *Astraptes fulgerator* complex by the following combination of character states of the DNA barcode: 38T; 52T; 202T; 205C; 274T; 568A. 202T and 568A are unique fixed states for *A. favilla* with respect to other members of the *A. fulgerator* complex.

Holotype. Voucher 02-SRNP-31536, deposited at the University of Pennsylvania.

Note: This species corresponds to the OTU 'TRIGO' of Hebert *et al.* (2004).

Etymology. The name *favilla*, a feminine noun in apposition, means 'smouldering embers'. The species is named in recognition of the skipper taxonomist John M. Burns.

Relaxed biological species



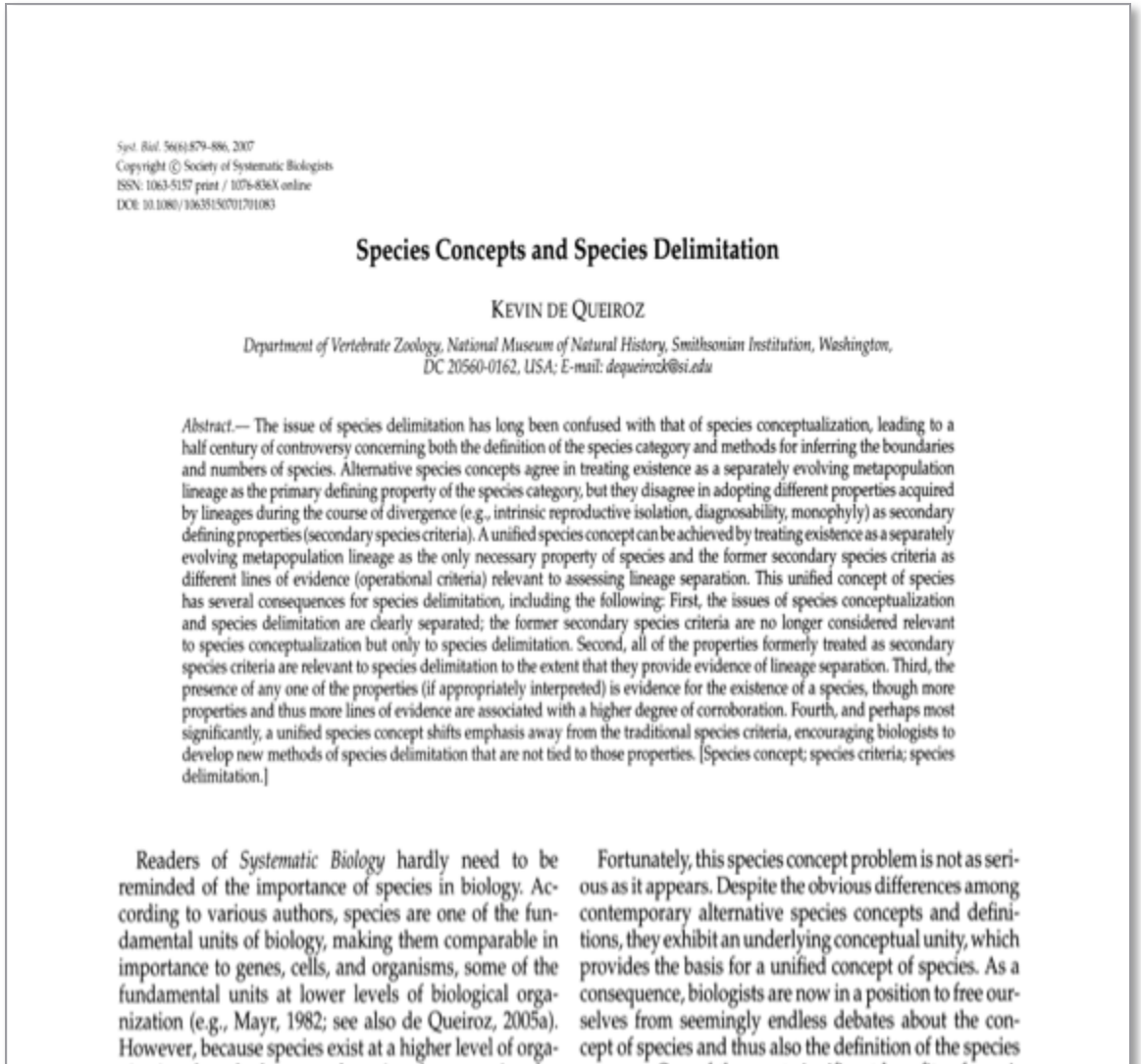
- **Species definition:** limited (i.e. not necessarily zero!) gene flow + presence of reproductive barriers

- **Species recognition:** usually by proxy characters, i.e. morphological or genetic markers

- **Allopatric populations and fossils:** considered as species if they differ from each other at least in the extent as usual sympatric species do

- **Paraphyletic and polyphyletic species:** impossible to solve, as at the gene level the speciation (usually temporarily) violates the monophyly

Unified species concept



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Species Concepts and Species Delimitation

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Abstract.— The issue of species delimitation has long been confused with that of species conceptualization, leading to a half century of controversy concerning both the definition of the species category and methods for inferring the boundaries and numbers of species. Alternative species concepts agree in treating existence as a separately evolving metapopulation lineage as the primary defining property of the species category, but they disagree in adopting different properties acquired by lineages during the course of divergence (e.g., intrinsic reproductive isolation, diagnosability, monophyly) as secondary defining properties (secondary species criteria). A unified species concept can be achieved by treating existence as a separately evolving metapopulation lineage as the only necessary property of species and the former secondary species criteria as different lines of evidence (operational criteria) relevant to assessing lineage separation. This unified concept of species has several consequences for species delimitation, including the following: First, the issues of species conceptualization and species delimitation are clearly separated; the former secondary species criteria are no longer considered relevant to species conceptualization but only to species delimitation. Second, all of the properties formerly treated as secondary species criteria are relevant to species delimitation to the extent that they provide evidence of lineage separation. Third, the presence of any one of the properties (if appropriately interpreted) is evidence for the existence of a species, though more properties and thus more lines of evidence are associated with a higher degree of corroboration. Fourth, and perhaps most significantly, a unified species concept shifts emphasis away from the traditional species criteria, encouraging biologists to develop new methods of species delimitation that are not tied to those properties. [Species concept; species criteria; species delimitation.]

Readers of *Systematic Biology* hardly need to be reminded of the importance of species in biology. According to various authors, species are one of the fundamental units of biology, making them comparable in importance to genes, cells, and organisms, some of the fundamental units at lower levels of biological organization (e.g., Mayr, 1982; see also de Queiroz, 2005a). However, because species exist at a higher level of orga-

Fortunately, this species concept problem is not as serious as it appears. Despite the obvious differences among contemporary alternative species concepts and definitions, they exhibit an underlying conceptual unity, which provides the basis for a unified concept of species. As a consequence, biologists are now in a position to free ourselves from seemingly endless debates about the concept of species and thus also the definition of the species

Different groups of biologist focus on different aspects of species and consider those as crucial :

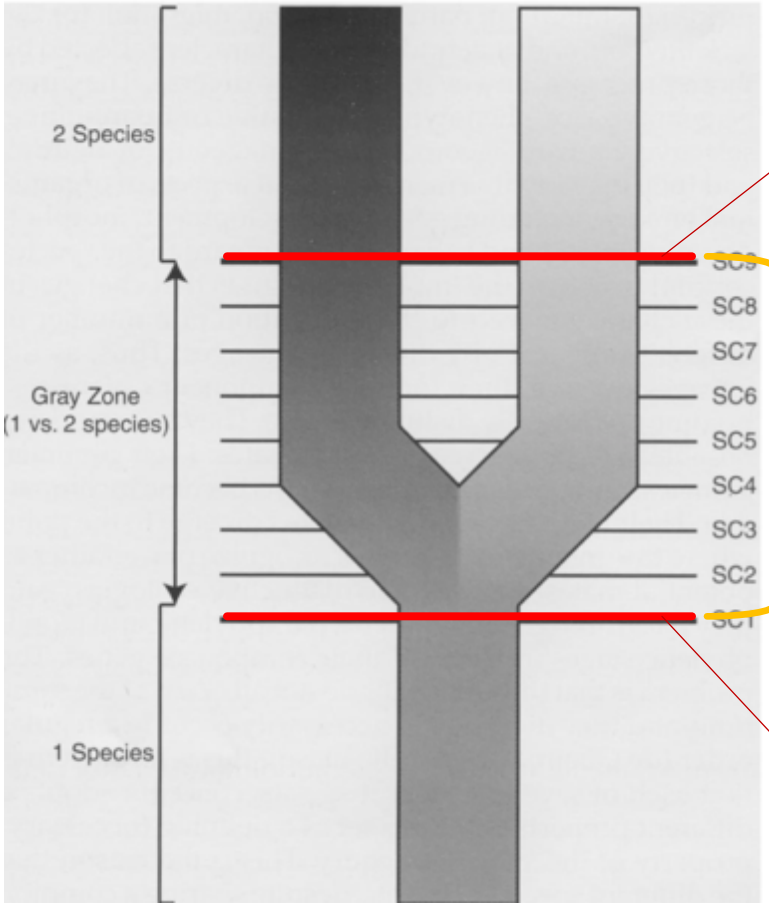
- reproductive isolation– population genetics, hybrid zones studies
- niche differences – ecologists
- monophyly, diagnosability – systematic zoology
- morphological differences – paleontologists, museum curators
- genetic differences – population genetics, molecular systematics

All species concepts in combination are useful to properly delimit species

Unified species concept

Six blinds and an efephant

Unified species concept



Everybody agrees that these are 2 species

Problematic zone:

- species acquire properties one by one
- one or two species based on different species concepts

Differences accumulate randomly
(some present before speciation starts, some evolve in the course of speciation, other appear after the speciation is finished)

Everybody agrees that this is one species

Unified species concept

***Bembidion chalceum* species complex** (Maddison 2008)

	chalceum	rothfelsi	bellorum	lousiella	antiquum
Different no. Chromos.	yes	yes	no	no	no
Monophyletic - CO1	yes	yes	no	yes	yes
Monophyletic – ArgK	no	yes	yes	yes	no
Differences in seq. - CO1	yes	yes	yes	yes	yes
Differences in seq. – wg	yes	yes	yes	no	no
Allopatric ranges	no	no	no	yes	no
Different ecological niche	no	no	no	no	no
Unique male genitalia	yes	yes	no	no	yes

Unified species concept

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FOR

- chromosome and genetic differences morphological differences

AGAINST

- problems with monophyly
- live in sympatry and occupy the same niche

Unified species concept

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FOR
- genetic differences
- allopatric ranges

AGAINST
- no chromosome differences
- problems with monophyly
- no morphological differences

Unified species concept

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- presence of property supports the hypothesis of separate lineages (species)
- absence of one or more the properties does not contradict the hypothesis of two separate lineages (species)
- well supported hypothesis = needs multiple proofs