Using Trees for Classifications

The Phylogenetic taxonomy

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Introduction

• The impulse to characterize and classify species - Ancient

– Aristoteles (384 - 322 B.C.), a philosopher of ancient Greece, was the first ever to create systematic biology.
• Increase of biodiversity knowledge

  – Hard to study and localize specimens in collections

  – Single species with different names

  – Search for a logical organization for nature diversity

• First systems of classification

  – External Morphology

  – Compared anatomy

  – Function of organs

• Methodists - Natural history

  – Class, Section, Genus and "differentia specifica"
• Carolus Linnaeus (1707-1778)
  – Hierarchical categories
    • Class
    • Order
    • Genus
    • Species
    • Variety

  – Binomial scientific nomenclature
    • XIX Century

• Linnaean system of taxonomy
  – Internacional Codes of Nomenclature

Acceptance of an evolutionary point of view

• Darwin origin of species
• Hennig
  – Tenet of common descent
    • Fundamental shift in outlooks concerning the role of the concept of evolution in taxonomy
    • Caused changes in systematic analysis
Acceptance of an evolutionary point of view

- Although the principle of common descent gained wide acceptance, it assumed superficial role in taxonomy
- It has not become a central tenet from which taxonomic principles and methods were derived
- Pre-existing Taxonomies - result of evolution

Acceptance of an evolutionary point of view

- Until recently biologists had not developed a phylogenetic system of taxonomy
  - Continued use of the Linnaean system
    - Modified
    - Elaborated
    - To accommodate the representation of phylogenetic relationships
Acceptance of an evolutionary point of view

– Some authors disagree that ad hoc modifications of body conventions based on a pre Darwinian world view is the most effective way to develop a phylogenetic system of taxonomy

• "Resistance to the Darwinian revolution"

PhyloCode

• International Code of Phylogenetic Nomenclature
  – De Queiroz et al.
  – Recognition that the current rank-based systems of nomenclature (botanical, zoological and bacteriological) are not well suited to govern the name of clades.
  – System of phylogenetic classification require names that explicitly and unambiguously refer to clades and do not change over time
The problems with Rank-based taxonomy

- Linnaean Categories
  - Kingdom, Phylum, Class...
  - Convey information about relative position of taxa (rank) in taxonomic hierarchy
  - Categorical assignments of taxa are by themselves insufficient to specify relationships
    - Internested
    - Mutually exclusive

- Often taxonomy contradicts phylogenetic relationships

- Value of certain characters
  - Distinctiveness X Common Ancestry

http://evolution.berkeley.edu
The problems with Rank-based taxonomy

- Mandatory Categories
  - Most Evident in organisms part of ancestral populations
    - Not part of clades less inclusive than the one stemming from their own population
    - Recognizing taxa at all mandatory levels implies the existence of clades that don’t exist - impose equal distance among them
    - Convention irreconcilable with phylogenetic taxonomy

De Queiroz & Gauthier (1993)
The problems with Rank-based taxonomy

- Although various descendants are different distances from the common ancestor at the base of phylogeny, they are forced into taxa representing all of the mandatory categories, which imposes equal distances upon them.

The problems with Rank-based taxonomy

- Synonymy and priority
  - If sister taxa originally considered to be two families are later judged to represent a single family, their names are synonyms.
  - Change association with their names with particular clades.

Instability of the phylogenetic meaning of Chamaleonidae

A: The clade name Acrodonta is ignored for not having familial terminology.
The problems with Rank-based taxonomy

- Formation of species names
  - Genus: mandatory category
  - If a given species is no longer considered to be part of a genus, it would be relocated
  - Instability of species names

The problems with Rank-based taxonomy

- Redundancy
  - Monotypic taxa
    - Reflect distinctiveness
    - Phylogeneticists reject distinctiveness as a justification for assigning a taxon to a Linnaean category of high rank because it sometimes results in paraphyletic taxa
The problems with Rank-based taxonomy

• Principle of Subsidiary Taxa
  – If nonmandatory Category level is used within any taxon, it’s used to all members of that taxon.
  – Ex: Subfamilies
  – Recognition of new taxa which evidence of monophyly is lacking

• Proliferation of categories

Taxonomy without Linnaean Categories

• Categories are neither necessary nor sufficient for conveying phylogenetic relationships

• Eliminating Linnaean categories
  – Not as radical
    • Don’t require change in the names of taxa (spelling)
    • Suffixes would be retained, but would not imply anything about Categories
Taxonomy without Linnaean Categories

• Binomials
  – A phylogenetic system of taxonomy cannot retain the Linnaean method of forming binomials
    • First name would not be a name of any rank
      – Forename or Praenomen
    • Binomials or uninomials
    • Species with the same praenomen would not necessarily be more close related
  – Guarantee stability of names of species
    • Eliminate alterations caused by changes in generic assignment
    • Include ancestral species in taxonomy

Taxonomy without Linnaean Categories

• Definitions of taxon names:
  – Reformulation
  – Organismal traits $\Rightarrow$ Phylogenetic relationships
  – Common ancestry is fundamental to the meanings of the names used to define groups of organisms
  – 3 classes of phylogenetic definitions (De Queiroz & Gauthier, 1990)
    • Node, stem and apomorphy-based
Phylogenetic definitions

• Different names can be defined so that they refer to different clades in a series of increasing inclusiveness
  – Eliminate redundancy of monotypic taxa

  – A taxon as a named clade consists not only of those organisms recognized as its members, but also ancestors and descendants, extant and extinct, known and unknown
Taxonomy without Linnaean Categories

- Synonymy and Priority in phylogenetic system
  - Taxon names are synonymous only if they refer to the same clade
  - Priority is based on the first use of a name to a particular clade
    - The valid name is not necessarily established by priority

\[ A = \text{Acrodonta} \]
\[ C = \text{Chamaeleonidae} \]

Taxonomy without Linnaean Categories

- Standard Names
  - Vast number of taxon names: some more widely known
  - Important to standardize the meanings of these names to ensure references to the same entities
Taxonomy without Linnaean Categories

• **Aves**
  - *Archaeopteryx*
  - *Apomorphy-based name*
    - Clade stemming from the first vertebrate possessing feathered wings

![Diagram 1](image1)

![Diagram 2](image2)

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Taxonomy without Linnaean Categories

• **Mammalia**
  - *Crown clade*
    - Stemming from the immediate common ancestor of sister groups with extant representatives
  - *Crown clade + extinct species*

![Diagram 3](image3)

![Diagram 4](image4)

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Taxonomy without Linnaean Categories

- Because of the way in which important names are most often used, the phylogenetic meaning of many widely known taxon names are most effectively standardized by tying them to clades within which both branches of the basal dichotomy are represented by extant descendants.

- Assure neontologists and paleontologists to refer to the same clade.
Taxonomy without Linnaean Categories

• More inclusive groups
  – “total groups” or “panmonophyla”
  – Stem-based groups: true sister groups
    • Equivalent in age

Conclusion

• The taxonomic system developed by Linnaeus, and formalized in the various codes of biological nomenclature, has governed taxonomic practices for over 200 years, however a phylogenetic system of classification which seeks to reformulate taxonomic principles and rules in terms of the tenet of common descent is developing and might replace the former