Systematics: Organizing Life's Diversity

36-149 The Tree of Life

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Plan

Life on this planet is fundamentally complex. Understanding the diversity of life, and thus how living things evolve and function, requires that we grapple with this complexity.

We will start by looking at some of the techniques used to understand and organize complex systems.

We will then see all these techniques employed in *systematics*, which is the science that encompassing identifying, naming, and classifying species and deducing their evolutionary relationships.

Dealing with Complexity

The world we observe is deeply complex.

One way to understand this complexity is to find simpler ways to think about it.

Two methods scientists use to simplify things are modeling and classification.

Dealing with Complexity (cont'd)

Modeling is the process of describing a system in simplified or idealized terms, usually mathematical or computational.

Models are built from assumptions about how the system works.

A useful maxim: All models are wrong, but some are useful.

- What models are you familiar with?
- How do they simplify the system they describe?
- How have you used modeling to understand something complex in your life?
- How do you check the assumptions of your models?

Dealing with Complexity (cont'd)

Classification is the process of dividing a set of items into "related" groups (often called classes), associating each item with a unique class.

The notion of relatedness in classification is quite flexible.

The trick is often to find classes that accurately represent the relationships.

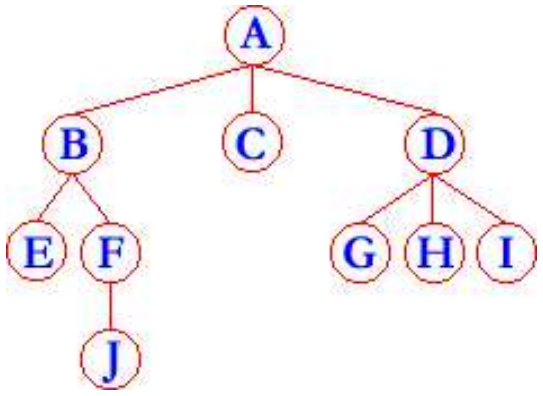
- What classification schemes are you familiar with?
- How are they used?
- How have you used classification in your life?
- How do you decide when classification is effective?

Organizing Complexity

- We organize a complex set of items by considering the *relationships* between items.
- Examples of organizational schemata:
  - Hierarchies: nested collection of groups arranged in "grades" or ranks.

    Aggregative versus Constitutive. Strict versus Cumulative. Examples.
  - Networks: collection of linked nodes. A node represent the objects and a link represents a relationship between them.
  - Trees: a special a network with only one path between any two nodes.
- Trees are of central importance for us this semester.

Trees



- A is the *root node* (or just *root*) of the tree.
- E, J, G, H, and I are the *leaf nodes* (or just *leaves*) of the tree.
- A is the *parent* of B, C, and D; B, C, and D are the *children* of A.
- What other parent-children relationships do you see?

A tree can be "hierarchical" or not. Examples?

Each object in a tree appears just once. In contrast, each object can be present at several levels of a hierarchy.

The most important trees we will consider are those derived from descent relationships.

. . . by any other name

Common names for organisms can be confusing!

- Many names for one organism
  - *Rosa canina*

    Briar Rose, Dog Rose, White-flowered Rose, Dog Briar, Hondsroos, Redoute Rose,

    Rosa sylvestris alba cum rubore folio glabro,
    Rosa sylvestris inodora seu canina

  - Rats!

    Rattus norvegicus: Brown Rat, Norway Rat, Sewer Rat, Laboratory Rat, White Rat

    Rattus rattus: Black Rat, Roof Rat, Tree Rat, Ship Rat, European Black Rat

  - *Tachyglossus aculeatus*

    Echidna, Short-beaked Echidna, Spiny Anteater, Jezura

. . . by any other name

- Name can vary with place and language too.

  Boletus edulis

USA	King Bolete	Italy	Porcini
France	Cepe	Germany	Steinpilz
England	Penny Bun	Sweden	Stensopp
Poland	Borowik	Finland	Herkkutatti
Spanish	Rodellón		

- One common name, many species

  Brown bat, yellow sac spider, spotted tick, . . .

- You get the idea. . ..

Why Worry?

Naming and classifying serve several useful ends:

- Avoids confusion.
- Aids in description of a complex set.
- Produces (useful) predictions.
- Explains relationships among disparate objects.
- Saves lives!

Linnaeus and the *Systema Naturae*

- Since Aristotle, naturalists had been grappling with how to name and classify organisms.
- Carolus Linnaeus (a.k.a. Carl von Linné) was a Swedish physician and botanist, who is often called the father of taxonomy.
- Gained access to vast (for the time) collections of specimens from around the world.
- Linnaeus's *Systema Naturae* was his classification of living things, published first in 1735 and repeatedly revised.

  The 10th revision (1758) is taken as the official beginning of formal taxonomic classification.

The Linnaean System

- Two contributions: a system of nomenclature (naming) and a system of classification.
- Nomenclature
  - Standardized format and language for scientific names
  - Formal introduction of the binomial name *Genus species*
- Classification

  Hierarchical grouping of all organisms.

  Original system of taxonomic ranks: Kingdom, Class, Order, Genus, Species

  Later biologists extended to Kingdom, Phylum, Class, Order, Family, Genus, Species; then, many intermediate ranks were added, including Domain above Kingdom.

Fine Distinctions

- *Systematics* is a biological discipline that encompasses three basic activities
  - Identification: description of species
  - Taxonomy: naming and classification
  - Phylogenetics: deducing evolutionary relationships

  (Some definitions are narrower, equating systematics and phylogenetics.)
- taxon (plural: taxa) – a named group of organisms; or, a unit of classification in a taxonomy.
- clade – a group of organisms that includes the most recent common ancestor of all members in the group and all descendants of that common ancestor.

Rules of Taxonomic Nomenclature

- Binomial names.

  A genus name is one word, with an initial capital. A species name is two words, a genus plus another word. These are italicized or underlined in print. Genus may be abbreviated (*T. rex*). The second word (e.g., rex) cannot appear alone. One name per taxon, please.

- Latin or Latinized names.
- Authorship.

  The original describer and the date of publication is given after the binomial name, though the names are often abbreviated. If the name is changed, the original "author" is given in parentheses and the new author afterward.

  Taphrina cerasi (Fuck.) Sad. Paging Herr Doktor Karl Wilhelm Gottlieb Leopold Fuckel; you have a phone call from Dr. Richard Emil Benjamin Sadebeck.

Rules (cont'd)

- Priority. Whoever described it first gets to name it!

  Scrotum humanum Brookes, 1763. Let's just stick with *Megalosaurus*, if you don't mind..

- Types. A valid name must have a "type specimen" available for examination.

  For *H. sapiens* Linnaeus, 1758, the type specimen is the skull of paleontologist Edward Cope.

- The three codes (Zoological, Botanical, Prokaryotic) are independent.

Amusing Examples of Taxonomic Names

- *Gelae baen*, *Gelae belae*, *Gelae donut*, *Gelae fish*, and *Gelae rol* Miller and Wheeler, 2004 [fungus beetles]
- *Orizabus subaziro* Ratcliffe [scarab beetle]
- *Phthiria relativitae*
- *Saurus soarus* [a gliding lizard]
- *Bison (Bison) bison bison* (Linne, 1758) Skinner & Kaisen, 1947 [What could this be?]
- *Pheidole harrisonfordi* Wilson, 2002 [Not a snake, he *hates* snakes.]
- *Plato* [A genus of spiders. Why??]
- *Frodospira* Wagner, 1999 and *Smeagol* Climo, 1980 [Lord of the Gastropods]

A Tale of Two Dinosaurs

- *Brontosaurus* (Marsh, 1879) $\longrightarrow$ *Apatosaurus* (Marsh, 1877). OK.

- *Tyrannosaurus* (Osborn, 1905) $\longrightarrow$ *Manospondylus* (Cope, 1892). NOT!

Two Schools of Systematic Thought

- In this corner, weighing 175 pounds, known for a strong upper cut and a long reach . . . Carl Linnaeus.
- In this corner, weighing in at 180 pounds, renowned for his rapid combinations and elegant footwork . . . Charles Darwin.
- OK, not *exactly* . . .

  But there are important distinctions between two schools of systematic thought:

  – Linnaean/Gradistic/"Evolutionary" Systematics

  – Darwinian/Cladistic/Phylogenetic Systematics

  They main distinction is in how the two systems define a taxon – the basic unit of classification.

Two Schools of Systematic Thought (cont'd)

- Gradistic Systematics
  - Based on morphological similarity
  - Graded into a hierarchy of ranks (e.g., Kingdom, Phylum, Class, Order, Genus Species) that include all organisms.
  - All members of a taxon must have a common ancestor that is also a member
  - But descendants can be excluded if they have developed distinctive featuers
  - Subjective: only organisms of the "same grade of development" are grouped together (e.g., Snakes-Lizards, Birds-Reptiles)

Two Schools of Systematic Thought (cont'd)

- Cladistic Systematics
  - Based strictly on descent ("closeness of ancestry") as determined by the structure of homologous characters
  - Taxa include common ancestor and all its descendant (e.g., Birds are Dinosaurs)
  - Tree based but not hierarchical

Punchline

Blue Pages

Announcements

- Next readings are on-line, follow links on the blackboard page.
- Schedule sheets for meeting are here; be sure to sign up after class.
- Let me know if you have any questions.