Lecture 1 – Introduction and Importance of Systematics

I. Definition of Systematics. Systematics was formerly equated with Taxonomy.

Ernst Mayr defined Taxonomy as “the theory and practice of classifying organisms”.

As we’ll see, however, the current understanding of Systematics is much broader.

This breadth is sometimes represented by levels of taxonomy.

\( \alpha \)-Taxonomy – includes species descriptions, taxonomic keys, and diagnoses.

\( \beta \)-Taxonomy – includes identification of natural groups and biological classes.

\( \gamma \)-Taxonomy – includes study of evolutionary processes and patterns.

This broad view is sometimes called Biosystematics, and it explicitly includes the third (this term is much more commonly used by botanists than by zoologists.)

This broad sense is defined by the SSB as “the study of organismal diversity, including both the pattern of that diversity and the processes that have generated it.”

II. Roles of Systematics. The role of systematic biology has changed over the years.

A. Provide \( \alpha \)-taxonomy. This is really the classic hat worn by systematists and, as large vertebrate groups have become more thoroughly understood, this role was traditionally been somewhat trivialized. However its fundamental importance has been rediscovered as the current biodiversity crisis worsens. Obviously, it becomes critical to describe biodiversity before we lose it.

This is recognized by NSF, for example in its Biodiversity Discovery & Analysis program (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503666&org=DEB&from=home)

The fundamental importance of this aspect of \( \alpha \)-taxonomy to society is very apparent if we look at biomedicine. Of the 150 most commonly prescribed drugs in the U.S., 57% contain active ingredients derived from natural compounds, that is, extracted from biodiversity that’s been documented already.

The most recent estimate (Costello et al. 2013. Science 339:413-416. doi: 10.1126/science.1230318) is that there are \(~5\) million (± 3 million) extant macrobial species on Earth and we’ve only described 1.5 million of them.

There may be as many as 1 trillion (\(10^{12}\)) species (Locey & Lennon. 2016. PNAS 113:5970).

So, aside from the scientific importance, there is huge potential for enhancing pharmaceuticals & developing new treatments by emphasizing \( \alpha \)-taxonomy.

So \( \alpha \)-taxonomists will continue have an enormous impact on biology in general, as in biomedicine. Links between biodiversity and human health are easy to identify and we’re just scratching the surface.
B. Provide specimen identification. We provide id’s for both the public and other scientists.

This may be accomplished indirectly, through the publication of keys.

It may be accomplished directly. Specimens are sent to systematists typically associated with museums for ids. In fact, the USDA has several systematic entomologists whose role is to be available for high priority id of potentially damaging crop pests, especially those found on imported foods.

Members of the broader biological community (e.g., ecologists, physiologists) frequently aren’t trained to be able to differentiate among very closely related species, and systematists verify their putative id’s.

Mosquitoes can be very difficult to identify to species, but species differ in their role as a vector for malaria, West Nile virus, Dengue virus and other viruses. The US Army funds mosquito systematics labs that provide id. These are often accomplished using genetic markers.

C. Maintain Collections – This is, in a way, related to the second role in that reference collections are often required, even by experts, to provide reliable id’s.

Collections also serve other critical roles; they serve as a permanent archive:

For type specimens, the actual physical material that was used in describing species.

For voucher specimens. All ecological studies should prepare voucher specimens. This allows future workers to verify work.

For other specimens. These serve as a permanent record of a species presence at a particular locality at a particular point in time. This is critical in that (1) it allows for the documentation of biotic change (range shifts), and (2) it can provide specimens from extirpated populations. In addition, these collections can serve as a source of genetic information for extirpated populations and species.

D. Classification – Order biological diversity into a hierarchical scheme of names.

~ 5 Million species

Goal is to provide a framework of names that is universal (applies to all of life) and stable (changes over time as little as possible). This framework provides a means of communicating across languages and cultures. Most importantly, this classification must reflect phylogeny. In addition, classifications lose their function as vehicles for communication if they are not stable.

Taxonomic revisions should only be proposed/utilized if current taxonomy conflicts with strong phylogenetic evidence. That is, we should not alter taxonomy in an attempt to equilibrate ranks, for example so that no genus is older than, say, 2 MY (see Pauley et al. 2009. Herpetologica 65:115; for an opposing view, see Patterson and Norris. 2016. Mammalia 80:241 for an opposing view).
E. Phylogeny Estimation – Inference of the hierarchy of common descent.

This is the primary focus of this course, and lots of methods have been devised to attempt this. It’s incredibly important – as of 01/09/17, a search of the Google Scholar database using “phylogeny” returned > 869,000 papers published.

Examples of Uses (in addition to traditional use in classification):

Understanding Adaptation.

Study of Evolutionary Patterns and Processes
- Co-speciation – for example between parasites and their hosts.
- Historical Biogeography – molecular phylogeography.
- Hybridization.
- Gene Duplication and Genome Structure.
- Deep-time evolutionary Patterns.
  - extinction and speciation rates (e.g., lineages-through time)
  - species selection and the study of evolutionary trends
  - key adaptations that allow a group to be speciose
  - study of correlation of traits or characters – comparative biology

Conservation Biology
- Given the ongoing biodiversity crisis and the limited resources that society allocates to conservation issues, a need arises to prioritize conservation efforts. Phylogeny estimation has been proposed as a means for determining these priorities.


Forensic Evidence – Statistical phylogenetics have been used recently to connect a Louisiana physician to a patient who was the source of HIV used to infect his mistress intentionally (Metzker et al. 2002. PNAS, 99:14293). This was the first time that phylogenetics have been accepted as forensic evidence.

The broad range of disciplines that this represents has a number of effects.

First, it leads to the diversity of student backgrounds in classes such as this.

Second, it leads to the diversity of backgrounds of scientists who use phylogenetics in their research. If you look at papers that present some type of phylogeny, many of the analyses are very poorly done and sometimes results are simply misinterpreted.

Third, there has been a huge infusion of computer scientists and mathematicians into development of phylogenetic methods. Sometimes these folks are unaware of the historical development of the field, which, as I’ll detail in the next lecture, has been contentious and absurdly vitriolic.