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# Systematics

## What is systematics?

Systematics is the study of the units of biodiversity.  Systematics differs from ecology in that the latter is concerned with the interactions of individuals (and therefore species) in a particular time, while the former is concerned with the diversification of lineages through time. Systematics includes the discovery of the basic units of biodiversity (species), reconstructing the patterns of relationships of species at successively higher levels, building classifications based on these patterns and naming appropriate taxa (taxonomy), and the application of this pattern knowledge to studying changes in organismal features through time.  It also includes the building and maintenance of biodiversity collections, upon which all the products of systematic studies are based.  These are museum collections of preserved specimens of all kinds.

Systematics has undergone a revolution in its basic paradigm over the last 50 years.  This revolution is just the latest step in a progression that has paralleled advances in other academic disciplines through the history of man.  Some concept of relationship -- the idea, for example, that a bluebird is more like an ostrich than it is like an antelope -- has existed since the early sentience of man.  During the 1700's, very basic, utility-driven systems of classification (such as those used by the herbalists through the Middle Ages, and, notably, by Linnaeus) began to be replaced by "natural" systems that were based on a comparison of large numbers of features, or characters, of the organisms under study.  During the next century, the concept of evolution gave causal explanation for the patterns that were being observed -- for how a group of jawbones in reptiles could be transformed into the ear bones of mammals, as an example.  A new classification criterion was then possible -- that taxa be grouped according to evolutionary relationship.  An intrinsic part of this idea is that groups of organisms change over time.  Yet it took until the middle of the 20th century for biologists to realize that it is the changed form of a character in time, the "advanced state", that gives us the best clue to phylogenetic relationships and that can be used to group organisms together because it signifies that they share a common history.  This realization is the key component to the methodology known as cladistics, which is our current systematic paradigm.  The method uses these advanced characters, or synapomorphies, to produce explicit, testable patterns of phylogenetic relationship among organisms.  In recent years, researchers have continued to refine the methodology, seeking the best ways by which to analyze character data to produce these patterns, as well as devising methods for evaluating the strength of these hypotheses, developing new sources of character information, and realizing the power of the resulting patterns when applied to any questions that deal with the evolution of organisms or their characters.

The study of evolution is often considered to be closely related to systematics.  In fact, the two are essentially cause and effect.  Although systematics can be done without regard to any process, since in its starkest form it is only a study of patterns without regard to how they came about, most researchers see evolution as the causal agent for these patterns.  Hence, studies of evolution examine the processes, at the individual and population level, that lead to the patterns that we study in systematics.

# What are the roles and products of systematics in modern biology?

As the sub-discipline of biology that investigates relationships of taxa, systematics is the foundation for comparative biology. Comparative biology is that type of study that attempts to relate features of one organism, or type of organism, to features in another type of organism. This always is a question of homology, or sameness due to common evolutionary origin. In systematic studies we hypothesize homology of features among taxa and then gather data to test these hypotheses. This is important because appearance alone is often not a good indicator that features in different taxa are homologous -- many times similar structures will evolve independently in different lineages. If they are homologous, we expect that they will share many things because of their common ancestry, while if they are not, it is impossible to predict just how similar they will be. Hence, any study that asks why or how about a feature in more than one taxon, and draws comparative conclusions about them, rests on a systematic foundation.

We can identify specific roles for systematic studies and the patterns they produce, as follows:

**1. Systematists identify and document Earth's biodiversity, and organize this information in a form that can be utilized by others.**

A long-standing role for systematists is that of going into the field and collecting samples of organisms, then comparing them with known specimens in order to determine whether something significantly different has been found -- a new species. Such work depends upon the expertise of specialists who are intimately familiar with the natural variation in a particular group. This expertise can only be gained by first-hand experience with the organisms, both in the field and in biodiversity collections. Once species have been defined, names are given to them according to rules of nomenclature for the group. Higher level taxa (genera, families, etc.), which are successively larger assemblages of species, can then be named based on the phylogenetic relationships of the species. The resulting classifications provide a basis for communication about taxa for the scientific community and for the world at large. Because biodiversity collections are intended to be permanent, and are assembled over time, they provide a way of documenting change in the world's flora and fauna, and can therefore provide supporting evidence for phenomena such as human-caused climate change.

**2. Systematic patterns are hypotheses of the history of life and form the basis for modern classifications.**

Once we know what organisms exist, we can then ask questions about how they came to be as they are today. Phylogenetic analysis allows us to combine data from extant organisms with data from fossils to provide hypotheses of relationship -- to actually reconstruct the history of life. It allows us to determine, for example, which living taxa are most closely related to the dinosaurs, which characters may have been key to the success of the flowering plants, and how many times HIV may have shifted hosts (e.g., between simians and man). This is because our phylogenetic hypotheses are both hypotheses of relationships of taxa and of character transformation. These patterns are framed as hypotheses because they are always subject to testing by additional characters. We build classifications from well-supported phylogenetic patterns.

**3. Phylogenetic patterns that result from systematic studies, and classifications derived from them, have predictive value.**

Common ancestry means that organisms will share more or fewer character states depending upon how closely related they are. This principle can be put to immediate use when one seeks additional taxa that may possess a feature of interest found in a specific taxon. For example, the anti-cancer compound taxol was isolated from a particular species of conifer, the Pacific Yew (Taxus brevifolia). Where else would we look to find other sources of this compound? The logical place to look would be in taxa that are most closely related to T. brevifolia. Armed with information about relationships in the genus, researchers found taxol in a closely related species, the Euopean Yew (T. baccata). This alternate source is less costly and will alleviate pressure on the rarer T. brevifolia. There is no guarantee in cases such as this that we will find what we are looking for, since the substance may have arisen only within one species, but rather than searching blindly, we increase our chances of success by looking in related species. Having the systematic guide for where to look is especially important in large groups (a genus of say, 500 species) to maximize use of time and resources. The list of biodiversity attributes of interest to man that such information can be applied to is endless, including all types of substances from, and characteristics of, organisms.

**4. Systematics provides a basis for biodiversity conservation priorities**.

With increasing pressures from a growing world population and resulting pressure on biotic resources, we now and in the future have to make difficult decisions about what parts of the Earth will be maintained in a "natural" state in order to conserve the biodiversity present there. How do we decide, given limited resources, which to protect? If we decide that we want to maximize biodiversity, then the phylogenetic patterns produced by systematists give us a way to prioritize areas based upon the diversity they contain. In order to maximize diversity, it makes sense to try to preserve groups from throughout the tree of life, rather than large numbers from one branch. In this way we will tend to preserve a wider array of features that have potential use for humans, though their uses may presently be unknown, but it does mean that we have to know something about the relationships of the organisms involved.

**5. Systematics provides independent evidence for patterns of geological change.**

The continents have not always held the positions on the Earth that they do today, nor have they been the same size and shape. Geologists use data from the Earth itself to reconstruct past arrangements of land masses. However, there is an independent source of data for such reconstructions, which lies in the current distribution of taxa when viewed in the light of their relationships. When land masses fragment or experience other fundamental change, the taxa that live on them record this change. By constructing organismal phylogenies and mapping on current distributions of taxa, and doing this for many groups, general patterns emerge that may best be explained by historical geological events. This is the objective of historical biogeography.

**6. Systematists and systematic collections provide identification services and documentation of identity.**

Another crucial role for systematists is that of identification specialists. They are in a unique position to provide this service, with experience and the necessary tools. The importance of correct identification cannot be overstated -- when a life, for instance, hangs in the balance depending on whether the plant or mushroom that has been ingested is poisonous or not, this service is critical. Other types of biological research are essentially valueless if their subjects are misidentified, since closely related taxa can have very different properties and generalizations must be made carefully. Hence, documentation is important so that subsequent investigators can confirm identifications. The only lasting way to document identity is to deposit a voucher specimen in an appropriate collection. Studies that do not utilize this service will have less value in the long term because of the impossibility of verifying identification.