TAXONOMY

Linnaeus's Last Stand?

A fight has erupted over the best way to name and classify organisms in light of current understanding of evolution and biodiversity

These days the once-serene hallways of the world's natural history museums are anything but tranquil. A small but powerful contingent of systematists is challenging more than 2 centuries of taxonomic tradition by proposing a new system for naming and classifying life, one they say is more in line with the current understanding of evolution. Their brash proposal, which will be debated at a symposium in Washington, D.C., on 30 and 31 March, has raised the ire of the more conservative leaders in the field. The resulting controversy over the new naming system, known as "PhyloCode," has pitted colleague against colleague, office mate against office mate. "You've got people willing to throw down their lives on both sides," says Michael Donoghue, a phylogenetic systematist at Yale University in New Haven, Connecticut.

Although few biologists pay rapt attention to systematics, the new proposal, if it prevails, could broadly affect how people think about the biological world. For more than 200 years, a Latin "first" and "last" name—genus and species—has been de rigueur for each organism on Earth. No matter what a person's native tongue or the common name of a species, "*Quercus alba*" identifies the same exact tree species—white oak—the world over. Yet under PhyloCode, which seeks to reflect phylogenetic relationships, genus names might be lost and species names might be shortened, hyphenated with their former genus designation, or given a numeric designation. The critics are not happy.

The traditional system groups organisms in part according to their resemblance to a representative "type" specimen and places them in a hierarchy of ever more inclusive categories called ranks that have helped people organize and communicate their thinking about flora and fauna. The new naming system would be based more explicitly on evolutionary relationships. Instead of being grouped into ranks, such as genus, family, and order, organisms would be assembled into "clades," defined as any set of organisms with a common ancestor.

Under PhyloCode, each clade's name would refer to a node in the tree of life and should thus provide nomenclature more appropriate for modern biological thinking, says the Smithsonian's Kevin de Queiroz, one of PhyloCode's developers. As such, it should simplify the current push to catalog millions of undescribed (and unnamed) species. "The inappropriateness and ineffectiveness of the current system in naming clades are obvious," asserts Philip Cantino, a plant systematist at Ohio University in Athens. "New clades are being discovered every day, but few are being named."

A sense of history. Museum collections drive home the breadth of change that might come about should a new way of naming organisms be adopted.

CREDIT: CHIP CLARK

Defenders of the Linnaean system disagree, maintaining that its shortcomings—and the advantages of PhyloCode—are exaggerated. "PhyloCode is an impractical and poorly founded system," says Jerrold Davis, a systematist at Cornell University in Ithaca, New York. But Davis is worried nonetheless. "There's just one group of people standing on the street corner making a lot of noise," he says. Yet, "it's starting to consume resources and starting to appear in the popular press as if these folks have won."

Taxonomic tradition

The Swedish botanist Carolus Linnaeus could not have anticipated the uproar that has erupted concerning the classification and nomenclature system he described in a 1758 book called *Systema Naturae*. At the time, names tended to be strings of descriptors that varied in length and meaning depending not just on the characteristics of the plant or animal but also on the scientist who named it. To enable botanists to equate plants from Europe, say, with plants from Turkey, Linnaeus devised a standardized system that has grown into the modern genus-species designation.

He also came up with basic principles for organizing newly named species into groups and then for assigning groups to specific taxonomic categories. His followers shaped this classification system into the "ranks" that have since been taught in every basic biology class. Thus humans are *Homo sapiens*, part of the genus *Homo*, the family Hominidae, the order Primate, the class Mammalia, the superclass Tetrapoda, the subphylum Vertebrata, the phylum Chordata, and the kingdom Animalia.

But in Linnaeus's mind, a species never changed—Darwin's observations about variation and evolution were still a century away. Thus, the Swede's system made no provision for naming and classifying organisms with evolutionary relationships in mind. "The Linnaean system was set up under a creationist world view to reflect a hierarchy of ideas in the eyes of the creator," explains Brent Mishler, herbarium director and systematist at the University of California, Berkeley. Furthermore, as far as Linnaeus could tell, life consisted of about 10,000 species. "The world was much more circumscribed than [the one] we have today," points out systematist Peter Stevens of the Missouri Botanical Garden in St. Louis.

Darwin's 19th century contemporaries maintained the Linnaean system. But as they learned more about the number and evolution of organisms, they found they had to devise ever more extensive nomenclature rules, or "codes"—one each for plants, animals, and microbes—that would guide researchers as they fit new species into the traditional ranked hierarchies and enable them to keep names and classifications straight.

Under the traditional system, a taxonomist begins by assessing the physical characteristics—say, petal or leaf arrangements a set of species has in common—then selects the most representative species to be the "type" for each genus, then the most representative genus to be the type of the family, and so forth. Individual specimens are then deposited in a museum to serve as the reference point for that species and genus. Thereafter, as new specimens with similar characteristics are found, they are deemed part of a known species, a new species, or even a new genus based on how closely they resemble the type specimen. In this way the original "type" becomes an anchor point for the ranked groups to which it belongs. Thus, the flowering plant *Aster amellus* is the type species for the genus *Aster*, which in turn is the type for the family Asteraceae and the order Asterales.

Because of this dependence on type species, if a systematist reassesses a group of organisms and concludes that certain members don't belong, this removal can sometimes mean that the group's name must

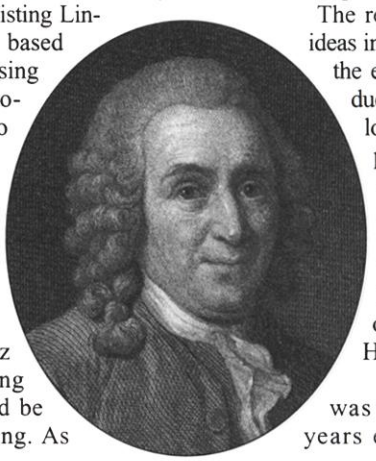
change, or a new group name must be created. Thus, when a group of herbs called *Ajuga* was added to the family called Teurcrioidae, that family had to be renamed for the herb's original family, Ajugoideae, because it was the older name. And because a common weed called henbit (*Lamium amplexicaule*) is the type genus for the mint family, any subfamily with *Lamium* in it must go by the name Lamiodeae. But over the past 35 years, *Lamium* has been reclassified three times—with each reclassification putting it into a new group. Thus three different subfamilies have borne the name Lamiodeae at one time or another. This ambiguity and these name changes are a hassle, say PhyloCode's advocates.

Another problem is that researchers unfamiliar with the intricacies of ranks often misinterpret them. For example, sometimes biodiversity is assessed in terms of numbers of families, but that ranking says little about the number of species contained therein. The family Hominidae has only one living species—*Homo sapiens*—while other families have tens, hundreds, or in the case of some plant families, even thousands of members. Because ranks are not always equivalent, a simple family count may give a false picture of an area's biodiversity. Even Peter Forey, a vertebrate paleontologist at the London Natural History Museum who supports the current naming system, agrees that "the Linnaean ranks … don't mean a lot in the modern-day world."

Time for a change?

These drawbacks became apparent to de Queiroz in the 1980s while he was a graduate student at the University of California, Berkeley. At the time, a new way of classifying organisms called cladistics, based on assessing the evolutionary histories of features shared by organisms, had begun to make its mark on the field. This was causing great rifts among systematists about how they should do their work, as existing Linnaean categories were not based on phylogeny. Like increasing numbers of his contemporaries, de Queiroz wanted to reclassify the organisms he worked on following the principles of cladistics; yet he wasn't sure how to apply the existing nomenclature codes to the groups, or clades, he came up with.

As a result, de Queiroz says, applying the existing nomenclature codes could be cumbersome and confusing. As he and his colleague Jacques Gauthier, now a vertebrate paleontologist at Yale, were writing up their work, he recalls, "we stumbled on the idea of developing a naming system depicting phylogenetic relationships. At the time we didn't realize the full significance of it."



Taxonomic pioneer. Linnaeus fathered our current naming system some 250 years ago.

As de Queiroz and Gauthier worked out the conceptual underpinnings of such an approach over the next 8 years, they began to wonder whether Linnaean taxonomy had outlived its usefulness. Thus was born the PhyloCode, and from the start, it didn't quite jibe with the Linnaean approach. For example, one way a PhyloCoder might define a clade would be to choose the two most distantly related organisms in that group as the "specifiers" and say that the group consisted of all those with the same last common ancestor as the specifiers. Such groupings didn't always coincide with previous membership in ranks.

The researchers described these ideas in several publications during the early 1990s, and then introduced them to the broader biological community at a symposium held during the 1995 meeting of the American Institute of Biological Sciences (AIBS). Interest was strong enough that de Queiroz and his converts organized a workshop at Harvard in August 1998.

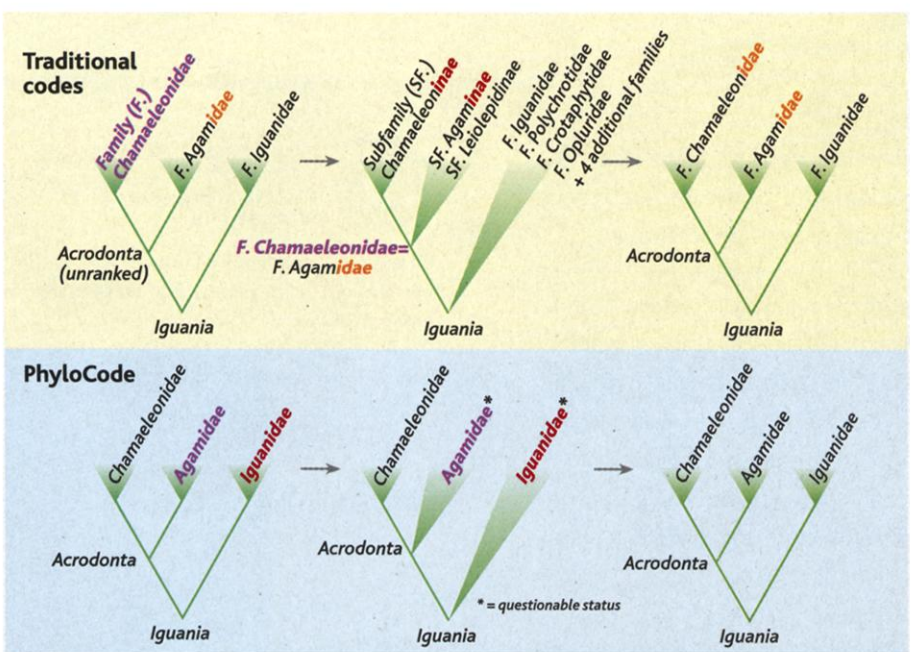
Among the 30 attendees was Ohio's Cantino, who 4 years earlier had "written off phylogenetic nomenclature as impractical," he recalls. But for the AIBS symposium, he had been asked to evaluate how the old and new approaches would work with the mint plants that he studies. As a result, Cantino says, "I realized that phylogenetic nomenclature has great advantages."

Cantino has since become one of the PhyloCode's strongest advocates. He helped de Queiroz polish rules for the new system that were developed at the 1998 workshop. In May 2000 he posted them on the World Wide Web for comment (www.ohio.edu/phylocode). As comments trickle in, momentum is building to establish a society to guide PhyloCode's continued development, says Yale's Donoghue.

Tough sell

Whereas almost all 21st century systematists now take a phylogenetic approach toward classifying organisms, PhyloCode presents them with an alternative to the Linnaean approach for naming what they classify. One key difference is that because organisms would be grouped in clades under the new system, names would include no references to families, orders, classes, even genera in the traditional sense. And the definition of each name, be it for a species or some more inclusive clade, would be based on the shared ancestry of its members.

PhyloCode advocates haven't settled what will happen to species names, but they insist that most Linnaean family, class, or order names will survive the transition and will usually cover the same array of organisms. Thus, there could be a clade called Asterales that included another, smaller clade called Asteraceae, and the traditional relationship of these two groups would be retained. "Critics have said you'd lose all



Name game. When new phylogenetic analyses reordered the lizard groups, the traditional Linnaean code led to changes in rank and therefore in names. The PhyloCode would not produce such changes.

CREDITS: (TOP TO BOTTOM) CORBIS; (SOURCE) KEVIN DE QUEIROZ

the hierarchical information, but you wouldn't," says Berkeley's Mishler.

In addition, PhyloCoders say that once a name has been redefined in PhyloCode terms, it should be more stable than it has been under Linnaean rules. For example, in the PhyloCode system, the addition of the herb *Ajuga* to Teurcrioidae would not have forced that name to be changed. Unlike in the Linnaean system, they say, the new definitions will allow for organisms to move in and out of clades without disturbing the clade's name or the names of the other organisms. In some ways, "PhyloCode is a more flexible naming system," Missouri's Stevens asserts.

Names-go-round. Because of Linnaean rules, the names of groups containing *Ajuga reptans (above)*, *Teucrium fruticans (top right)*, and *Lamium amplexicaule (lower right)* have changed through time.

Both sides agree that the names of living organisms should be stable. "You don't want a system of nomenclature that is too mushy, where the names have no meaning," says the Smithsonian's Frank Ferrari, a PhyloCode critic. But both sides vehemently disagree about which system provides the strongest guarantee that a name and its meaning will remain unchanged through the decades. In the Linnaean world, instability arises because names for the groups change as the group's members change. Yet in the PhyloCode world, say its critics, names may stabilize, but what they signify will change as new evolutionary studies cause members to shift from clade to clade—as is bound to happen.

Evolutionary biologists across the globe are busy rearranging many branches of the tree of life, often by comparing genetic material from a wide range of species. Sometimes analyses of one gene will lead to a different branching pattern than analyses of a different gene. Organisms, perhaps even those specifying a clade, may shift in and out of the clade accordingly. Thus, PhyloCode "is not stable to changes in the phylogeny," Cornell plant systematist Kevin Nixon contends. And he argues that Linnaean categories may be just fine, as they are being revised to better reflect phylogeny.

Nixon and others also see value in retaining the Linnaean ranks, even if they lack biological meaning. "They are extremely important to our ability to communicate information about the biodiversity that we see and study," he argues. When he teaches a class, he likes to be able to refer to families, so that if he's taking a class on a field trip, he can communicate about whole groups of trees. Clunky as the current system may be, it works, he insists, because of what family, class, genera, and other names have come to represent.

Despite being convinced that the Linnaean way is superior, Nixon is concerned about the headway PhyloCode is making. "[PhyloCode] is not going to die out, because the spinmeisters behind this have the ear of the large funding agencies," he complains. Even the upcoming workshop on Linnaean taxonomy at the Smithsonian National Museum of Natural History "will very much play into the PhyloCode [camp's] hands," Nixon predicts. At any rate, there's likely to be vociferous debate about the two systems at the meeting.

But what rankles Nixon and his loyal Linnaean colleagues the most, they say, is that PhyloCoders appear to have seceded from the taxonomic community. Several governing bodies exist to help enforce and clarify Linnaean codes of nomenclature, but PhyloCoders seemed to have bypassed both the codes and their congresses. "They are going to erect a shadow government and [set up] a coup," Nixon complains. "This is arrogance."

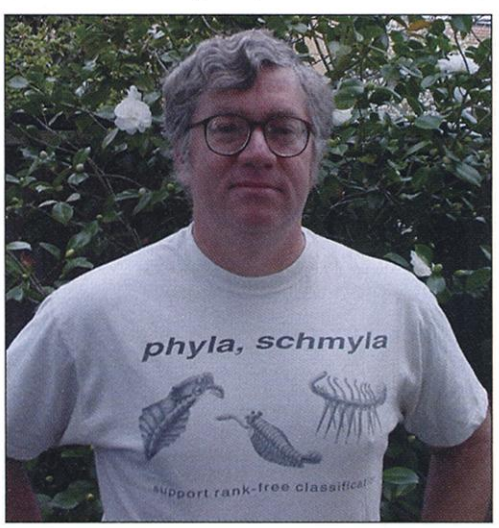
In their defense, PhyloCode supporters say they have no choice but to go outside the existing system. "The differences between phylogenetic and rank-based nomenclature are just too fundamental for them to be combined," Cantino argues. Furthermore, they say they need an organization that can help iron out the details of PhyloCode. One contentious issue: how to name species.

Many systematists, such as Stevens, want the names to remain the same. "The only reason to junk [a name] would be because it causes widespread confusion," he suggests. "You can add lots of higher order stuff by PhyloCode around the rudiments of the Linnaean system."

But in one popular proposal, just the "species" epithet would become the name. So *Homo sapiens* would get shortened to *sapiens*. Its drawback: Many organisms would need further qualification, as there are quite a few genera, for example, with a species named *vulgaris*, and searching archived literature for the "*vulgaris*" organism could yield many false citations. Another proposal calls for adding a number that might signify the place of a particular *vulgaris* on the tree of life, while a third calls for simply adding a hyphen to the existing genus-species designation, thereby linking them for all time. Although this yields a stable, unambiguous name, it could be misleading should phylogenetic studies later prove that one species didn't really share a common ancestor with another with the same genus name.

The lack of agreement about what to call species gives many systematists pause, even those who are open to PhyloCode. PhyloCode is "not ready for prime time," says Paul Berry, herbarium director at the University of Wisconsin, Madison. But the only way PhyloCode will make it to prime time will be if systematists take it seriously enough to test its potential. "One can never know for sure that one system is better than another until both have been tried for a while," says Cantino, who is nonetheless pleased about the volume of activity at the PhyloCode Web site. "Most of the negative reactions have come from people who have not visited the Web site," he notes.

He anticipates that continued feedback will lead to refinements, and that over the next several years, researchers will start naming organisms using both approaches. In this way, the relative shortcomings and merits of each will become apparent.



Poking fun. A few Harvard students favoring PhyloCode put their thoughts on a T-shirt, modeled here by Berkeley's Brent Mishler.

–ELIZABETH PENNISI

CREDITS: (FLOWERS) PHIL CANTINO; BRENT MISHLER