Should We Junk Linnaeus?

A bold band of taxonomists proposes to change the way every living thing gets named

By SUSAN MILIUS

Session 4.1 at the big International Botanical Congress in St. Louis drew an overflow crowd as some 200 chairs and most of the standing room filled with . . . what? That was the question.

The symposium speakers came from a small group of taxonomists who are developing a new approach to naming all living things. Although these insurgents did not dispute that the botanists packing the room were mammals, the speakers rejected the hierarchical notion that they were lecturing to representatives of the class Mammalia in the phylum Chordata.

Think of all those kingdoms, phyla, classes, orders, families, genera, and species that generations of biology students have groaned about memorizing. Get rid of them, urged the rebels. At the speed of modern science, that system is too hard to keep up to date. Down with Linnaean hierarchy.

Does that mean that the mammals clutching their green-and-white conference bags at the botanical meeting would no longer call themselves *Homo sapiens*?

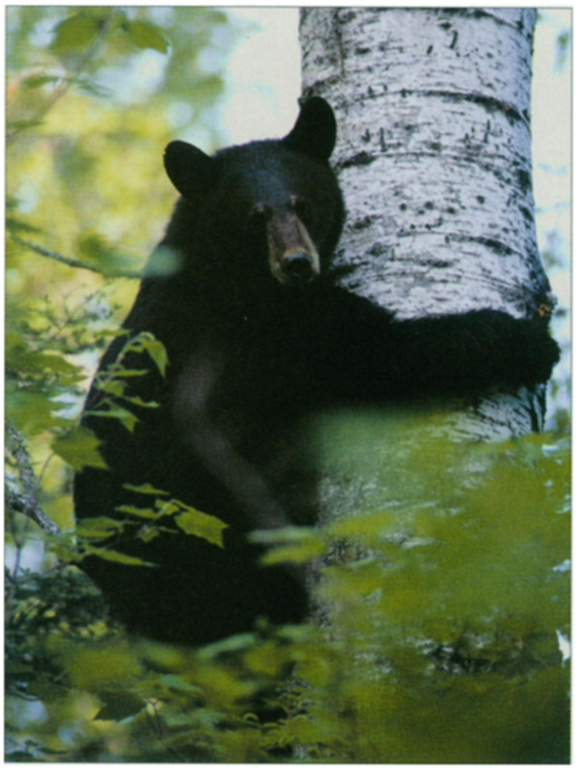
The new system's first working version of naming rules won't cover species, but the taxonomists are already discussing that topic. Kevin de Queiroz of the Smithsonian Institution in Washington, D.C., one of the chief drafters of the new rules, acknowledges that, yes, the human race might someday change its name.

The revision could be something mild like adding a hyphen, making people into *Homo-sapiens*. Then again, de Queiroz might have been addressing an audience of just plain *sapiens* or, according to proposals of registration numbers, *sapiens* [*7523*].

While species names might have been a side issue for the presenters, the topic incited some muttering in the audience. One *sapiens* [*7523*] clapped her legal pad onto the top of her head, as if in protection against the deluge of oddity.

De Queiroz and an international collaboration of about 30 taxonomists argue that this oddity will better handle the tsunami of evolutionary data and discoveries that threaten to swamp the old Linnaean system, developed more than a century before Darwin published his theory.

The revisionists refer to their new naming system as "phylogenetic nomenclature" and the opus, which the authors hope to unveil next year, as the PhyloCode. They intend it to be an alternative to the long-standing *International Code of Botanical Nomenclature,* a worldwide standard that the International Botanical Congress revises every 6 years.



All the beings in the tree of life could get reorganized into a new system without the kingdoms, phyla, classes, and other levels of the Linnaean hierarchy.

Taxonomists have been rejiggering the standard biological nomenclature system for all of the 264 years since Swedish botanist Carl Linnaeus published its first form. Still, according to Peter C. Hoch, the secretary general of the congress in St. Louis, most of the revisions to that code have been minor refinements. Although the phylocoders haven't converted him to their point of view, he sees their challenge to Linnaeus as more than the usual tweak. "This is a pretty profound new idea," he says.

Linnaeus had a pretty profound idea, too, for his day, but "there are many misunderstandings around this," says Kåre Bremer of the University of Uppsala in Sweden, a taxonomist who has studied the lore of his distant predecessor.

First, Bremer points out that although Linnaeus presented systems for both classification and nomenclature, only the naming system has endured. "His classification was already overthrown in the 18th century," Bremer says.

What has survived is Linnaeus' practice of identifying each organism by two names, the first for the genus and the second for the particular species within that genus. In the previous system, scientists named plants and animals in Latin with a full descriptive phrase, punctuation and all. For example, a briar rose was known as "*Rosa sylvestris alba cum rubore, folio glabro*" (pinkish white woodland rose with smooth leaves). No wonder people preferred Linnaeus' "*Rosa canina*" (dog rose).

In the so-called Linnaean hierarchy, Linnaeus stacked similar genera into groups, then put those groups into bigger sets. Actually, he didn't invent the idea of building a taxonomic hierarchy, Bremer says. Naturalists as far back as Aristotle had been nesting groups within groups. Linnaeus, however, enlarged that system, and subsequent scientists have added even more layers.

What startles Dan Lewis, curator of science collections at the Huntington Library in San Marino, Calif., about Linnaeus' first publication of his system is how short it was. *Systema Naturae*, published in 1735, standardized the names for plants and animals in only 14 pages. Admittedly, each page measured about 1 1/2 feet by 2 feet, a popular book size at the time.

For most of the 20th century, scientists contemplating the tree of life focused on the concept of species, but as for "the bigger picture—it wasn't in vogue," de Queiroz says.

What broadened the field again was the 1966 publication in English of a book by German entomologist Willi Hennig. While still relying on the standard Linnaean names, he elaborated what taxonomists now call the cladistic approach to classifying organisms. Hennig proposed refinements in ways to detect clades, groups of organisms that descend from a common ancestor.

Hennig's emphasis on sorting out relationships intrigued de Queiroz when he was a graduate student trying to trace the origins of lizards. For an academic project, he and fellow student Jacques Gauthier, who now teaches at Yale University, met every Friday to analyze lizard evolution.

As they sketched out trees of relationships, Gauthier decided that they should push to its extreme the idea of matching names to evolutionary history and restrict a name to a single clade originating from a species that has living descendants. That name would include the ancestor and its descendants, period, with no look-alikes tossed in.

"What I felt at the time was a revelation: 'Oh wow, this could be important,'" de Queiroz remembers. He and Gauthier used their new system, the beginnings of phylogenetic nomenclature, for a chapter in a book on lizards but then reached a wider audience with three papers in the early 1990s.

An outsider might assume that taxonomists have all along been revising names of organisms to match new information about their lineages, making the names fit history. De Queiroz and like-minded researchers say no, however.

"We are so far from achieving that that it's laughable," rails phylocoder Michael J. Donoghue of Harvard University.

If names are ever going to match evolutionary history, Donoghue argues, Linnaean nomenclature has to go. It can no longer cope with the scale of the discoveries of modern science, he says.

For one thing, the tree of life now towers over the puny sprout that Linnaeus knew. Even as he expanded his original 14-page list, Linnaeus could still name all known plants and animals in one volume. Now, however, the number of documented species has reached about 1.5 million, according to Donoghue, and that's just the beginning. He considers the most conservative estimate of species on Earth to be about 5 million.

This profusion of creatures raises the possibility of naming literally millions of clades, he points out. For example, someone might decide that humans and their close relatives the chimps form an interesting lineage to study and might give it a name. Backing away from this clade for a slightly larger picture reveals the human-chimp-gorilla clade, then eventually the clade of all primates, within the clade of all mammals, within the clade of the vertebrates and so on. "There are clades within clades within clades, and that's what the tree of life is all about," says Donoghue.

The complexity of that tree is indeed springing into focus these days, he notes. The resurgence of theoretical work on taxonomy that Hennig triggered coincides with a flood of gene-sequencing data that gives taxonomists new clues about what's related to what. Increasingly sophisticated computer algorithms crunch vast amounts of data into evolutionary trees. "Then, all hell breaks loose, and you discover all kinds of stuff," Donoghue says.

To dramatize the staggering amount of information on clades, at the International Botanical Congress he unfurled a printout of a phylogenetic tree that roughly covers flowering plants. The scroll, spider-veined with tiny lines tracing lineages, stretched for 12 ft. Scaling up, Donoghue calculated that a full phylogenetic tree for living things would extend almost 1 1/2 miles from the podium out through the St. Louis arch.

The trouble with applying Linnaean nomenclature to these scrolls, he argues, is that naming something requires that a taxonomist decide whether it's a family, an order, or some other rank.

In the Linnaean system, each name ends with a signal of its rank, like "-aceae" for plant families. Even with heroic efforts to bulk up the Linnaean rank system—inventing new categories like legions and cohorts and stretching the old ones by adding "sub-," "infra-," "giga-," or whatever—Donoghue doesn't see how the 20 or so categories could accommodate all the possible clades.

The thought of giving up these ranks scares people, Donoghue observes. "They say, 'I'm losing a lot of information, aren't I?'"

No, he answers, "it was illusion, anyway." Taxonomists picked ranks arbitrarily. Families or other groups don't necessarily mark lineages of comparable age or ecological diversity or size or anything else. "Those of us in the taxonomy business know this," Donoghue says. He calls the phylocoder's push to remove the ranks "a plea for truth in advertising."

PhyloCode is also a plea for an end to the cascading name changes that the current taxonomy requires. Revising one name under the current tightly interlocked naming system bumps closely related plants into slightly different ranks, setting off a stream of name changes and inviting confusion.

"Renaming goes on on a daily basis," grouses Donoghue. "We're busy. We have other things to do. It doesn't make sense for scientists to be doing things like this."

To cope with the volume of clades and to bring some stability to names, Donoghue envisions that the PhyloCode will permit a scientist to name any clade that seems important. The name persists even if the clade loses some of it members or is grafted elsewhere on the tree of life.

"Suppose I have discovered a clade—let's just call it Bob," he says. As a clade, it would contain an ancestor and all its descendants, perhaps the common ancestor of water lilies and sunflowers and all the lineages that have sprung from it.

As modern evolutionary information piles in, Bob might turn out to include a huge number of species from another part of the tree, or it might get transferred to the midst of what had been a different clade. Since the name Bob did not connote any rank, it could stay the same, as could the names of its new relatives. "I can do all this [with Bob], and it doesn't have any affect on Ted, Carol, or Alice," Donoghue explains.

This plan for name stability didn't immediately grab botanist Philip D. Cantino of Ohio University in Athens. "I had read [Gauthier and de Queiroz' 1992] paper when it came out and written it off as crazy, impractical stuff," he says. Then in 1995, he was invited to compare Gauthier and de Queiroz' approach with the old nomenclature by applying both to his botanical specialty, mints. As he worked on the presentation, Cantino changed his opinion, and he now works with de Queiroz as one of the writers of the PhyloCode.

"What drew me to phylogenetic nomenclature in the end was not its logical elegance—although it has that, too—but its practicality," Cantino recalls.

Steven Wagstaff

Cantino

The mint Teucrium fruticans *(left) and some close relatives form a distinct twig on the tree of life, according to botanist Philip Cantino. He named that group Teucrioideae, but the old Linnaean system required that he change the name when DNA evidence showed that the genus* Ajuga, *including* Ajuga reptans *(right), also belongs to it.*

The Linnaean system had led him, during one decade's work, to use the same name for three different groups of mints. The system also required him to change the name of a large clade formerly called Teucrioidae in the standard nomenclature. Recognizing that another genus belonged to it triggered vexing rules about name priorities, but phylogenetic nomenclature accommodates these changes gracefully, he says.

This flexibility won over botanist Kathleen A. Kron of Wake Forest University in Winston-Salem, N.C. When she wanted to name a lineage that she'd discovered within the heath group, she found that the only two options under standard nomenclature each required changing almost 100 other plant names. The new nomenclature demanded none.

As Cantino summarizes the issue: "Would chemists be satisfied with a system of nomenclature in which naming a newly discovered compound required renaming other compounds?"

As the phylocoders have presented their ideas, "reactions have been extreme and varied," Cantino says. "The day after [his presentation at the International Botanical Congress], I was approached by some people who were very enthusiastic about it and others who were appalled."

Taxonomist Alan Whittemore of the Missouri Botanical Garden in St. Louis told SCIENCE NEWS that "the so-called Linnaean system has been modified extensively over the past few generations to reflect phylogenetic thinking. It now works about as well as you could expect from any system of nomenclature."

Besides, he warns, "proposals to make very extensive changes in the way organisms are named have a very bad history. Many different schemes have been proposed over the years, and almost all of them have turned out to be impractical for one reason or another."

Congress Secretary General Hoch of the Missouri Botanical Garden does recognize the trouble caused when he and other taxonomists shift names. "The ecologists hate us; the horticulturists hate us. . . ," he laments. He still shudders to remember the plight of a colleague who reviewed the 25 or so species in the mustard genus *Arabidopsis* and discovered what Hoch calls an "awful mess."

Twenty of the species turned out to have no evolutionary relationship with *Arabidopsis thaliana*, yet the species is so widely used in plant-genetics labs that changing its name would be almost as controversial as redoing *H. sapiens*. To preserve the plant name according to the standard rules, the colleague shrank the genus to about five species and performed other fancy taxonomic footwork, says Hoch.

"Everybody can see the problem, but not many people are going to say, 'Let's throw the whole thing out,'" Hoch says. PhyloCode would "overburden the nomenclature system with too much information," he fears. "A guy doing a biological survey doesn't care what the next nearest relative is."

Who has to throw out anything? asks taxonomist J. Mark Porter of Rancho Santa Ana Botanic Garden in Claremont, Calif. He predicts PhyloCode will develop into "a parallel system and will require us to become bilingual." He doesn't envision that even herbaria, the bastions of botanical nomenclature, will suffer huge shocks. "Like Y2K, the fear of phylogenetic nomenclature is likely greater than its actual impact on herbarium management," he predicts.

That sounds fine to phylocoder Cantino. "I don't view what I'm doing as trying to topple the Linnaean system. We are simply making an alternative available," he says. "If the Linnaean system is eventually toppled, it will be through the will of the scientific community, not the efforts of a few individuals." □

Earth Science

Weather service's supercomputer burns

A fire late last month destroyed the primary supercomputer used for predicting the nation's weather, potentially lowering the reliability of forecasts for several months.

On Sept. 27, a fire broke out within the power pack of the National Weather Service's Cray C90 supercomputer in Suitland, Md. Firefighters quickly put out the flames, but they mistakenly used a calcium carbonate extinguisher instead of the carbon dioxide canisters in the computer room.

It was the calcium carbonate powder, rather than the fire, that caused irreparable damage to the computer, says Louis W. Uccellini, director of the National Centers for Environmental Prediction (NCEP) in Camp Springs, Md., which oversees the supercomputer operations.

The Cray C90 ran the weather service's primary forecasting models, which predict weather from a few hours to 16 days ahead. It also ran the foremost U.S. hurricane model, as well as the national El Niño model looking several seasons ahead. As a backup, NCEP has relied on two smaller computers to run most of the models, sometimes less frequently and at a reduced resolution. Other nations and the U.S. Navy and Air Force are also providing some computer outputs for NCEP.

"We believe all critical operations are being supported and our folks are doing their jobs," says Uccellini. The current limitations, however, have made it more difficult for meteorologists because they have less computer guidance for making forecasts. "There's more uncertainty in some of the products we issue," says Uccellini.

Even before the fire, the weather service had planned on retiring the 1994-vintage Cray. This year, NCEP purchased an IBM supercomputer capable of a peak speed of 690 billion floating-point operations per second (gigaFLOPS). The Cray's peak was 15.3 gigaFLOPS.

NCEP will start using the IBM on Nov. 15, but it may be a month or more before the new computer can take over all the functions of the old one, says Uccellini. —*R.M.*

Ozone hole is smaller than last year

The ozone hole over Antarctica this year fell short of 1998's record size, providing a piece of good news about the atmosphere's ability to recuperate from an overdose of pollutants.

"Before the patient can recover, it has to stop getting sicker. The hole doesn't seem to be getting bigger. This is the first indication that we have of what we expect," says David J. Hofmann of the National Oceanic and Atmospheric Administration in Boulder, Colo.

The ozone hole develops in the stratosphere over Antarctica in the Southern Hemisphere's springtime, when sunlight returns to the polar region. The light catalyzes chemical reactions involving chlorine and bromine pollutants that destroy ozone.

Satellite measurements reveal that the ozone hole was slightly smaller this year, covering an area of 25.0 million square kilometers on Sept. 15, compared with last year's record size of 27.2 million sq km, says Richard D. McPeters of NASA's Goddard Space Flight Center in Greenbelt, Md. (SN: 10/17/98, p. 246).

Satellite- and balloon-borne instruments showed that the amount of ozone over Antarctica bottomed out in early October at a value of 90 to 92 Dobson units, the same as last year.

Researchers have recently documented that the amount of ozone-destroying compounds in the atmosphere has stopped rising, thanks to international limits on these chemicals (SN: 3/9/96, p. 151). It will take a decade or more, however, before the ozone hole actually starts to shrink by a significant amount, says Hofmann. The difference between 1999 and 1998 resulted from year-to-year fluctuations in Antarctic weather, he says. —*R.M.*