A group of high school students sit in the school hallway cramming for a biology quiz. The bell rings, the students shove notes and textbooks into their bags and rush off to class. The quiz is on biological classification. Depending on the textbook, the teachers, and the state curriculum, these students learned to classify all live beings into three, or five, or six major groups, called either “kingdoms” or “domains.”

Taxonomy, the identification, naming, and classification of living things, is an indispensable unit in any biology curriculum and indeed, an integral part of biological science. Taxonomy catalogues life’s diversity and is an essential tool for communication. But it is more than that. Scientists endeavor to construct phylogenies, diagrams that, like family trees, show relationships among organisms through ancestral lineages. Thus modern classification systems are hypotheses about the genetic relationships among species and the evolutionary history of life.

Taxonomy is an especially dynamic field today. New molecular data, primarily DNA sequences, are available for an ever-increasing number of organisms. It appears that, as Emile Zuckerkandl and Linus Pauling predicted in 1965, molecules really are documents of evolutionary history. DNA sequences offer a way to quantify genetic similarity. Because DNA is universal, sequence data shed new light on evolutionary relationships, not only within esoteric groups of microbes but across the entire realm of life. The goal of a unified phylogeny appears within reach.

New Science, Old Standards

Where new data and interpretations outpace curricula, science teachers enjoy exciting opportunities to share cutting-edge research with students. But frustrating dilemmas arise: How should new information be incorporated into the framework of existing educational standards and materials? The committees that write state and national standards, authors of textbooks, and curriculum developers must also make decisions about how best to handle new developments.

The National Science Education Standards address taxonomy for grades 9-12 as follows:

Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

National Research Council, 1996

This standard describes the fundamental principles of biological classification without mentioning specific taxonomic systems. Many teachers, however, also answer to state or local standards.

Since 1996, I’ve observed several revisions in my state’s standards, the Massachusetts Curriculum Frameworks, which reflect the inherent difficulty in mandating what students should know in fields where methodologies and interpretations are controversial. Massachusetts has continually revised the expectations for student learning in biological classification, especially with regard to the number and kind of major categories of life. Presented below are the 2001 and 2006 high school life science learning standards for this topic.

In 2001, students were expected to be able to “describe how the taxonomic system classifies living things into domains (eubacteria, archaebacteria, and eukaryotes) and kingdoms (animals, plants, fungi, etc.).” The standard includes an additional note: “There is an ongoing scientific debate about the number of kingdoms and which organisms should be included in each. The following websites provide more information: Brave New Biosphere — whyfiles.org/022critters/phylogeny.html and The Tree of Life Project Root Page — phylogeny.arizona.edu/tree/phylogeny.html.”

As of 2006, Massachusetts students are required to “use cellular evidence (e.g., cell structure, cell number, cell reproduction) and modes of nutrition to describe the six kingdoms (Archeabacteria, Eubacteria, Protista, Fungi, Plantae, Animalia).”

Massachusetts has high-stakes testing; passing a standardized test based on the Massachusetts Science and Technology/Engineering Curriculum Framework is a graduation requirement. The committee that revised the Frameworks in 2006 no doubt felt pressure to resolve the ambiguity of the earlier standard.

Biology textbooks also reflect the current taxonomic debate. For decades, most biologists accepted the classification of all life into five kingdoms: Bacteria (or Monera), Protocists (protists and their macroscopic relatives), Animals, Plants, and Fungi (Figure 1). Since the 1980s, a system that replaces the five kingdoms with three domains (Bacteria, Archaea, and Eukarya) has gained support in the research community and made its way into newer textbooks (Figure 2). The six-kingdom system described in the 2006 Massachusetts learning standard represents a merger between the five kingdoms and the three domains; this six-kingdom scheme dominates the most recent crop of high school biology texts. In my district, for example, a 1997 textbook I had been using in seventh grade life science presents five kingdoms; its 1999 update includes six; and our high school biology text, from 2004, uses the three-domain system.

Five Kingdoms or Three Domains

To better judge educational standards and textbook discussions of taxonomy, I turned to the scientific literature. There I found proposals for anywhere from three to eight domains or kingdoms. The crux of the debate lies in the criteria for classification, the methods used to construct phylog-