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Patterns

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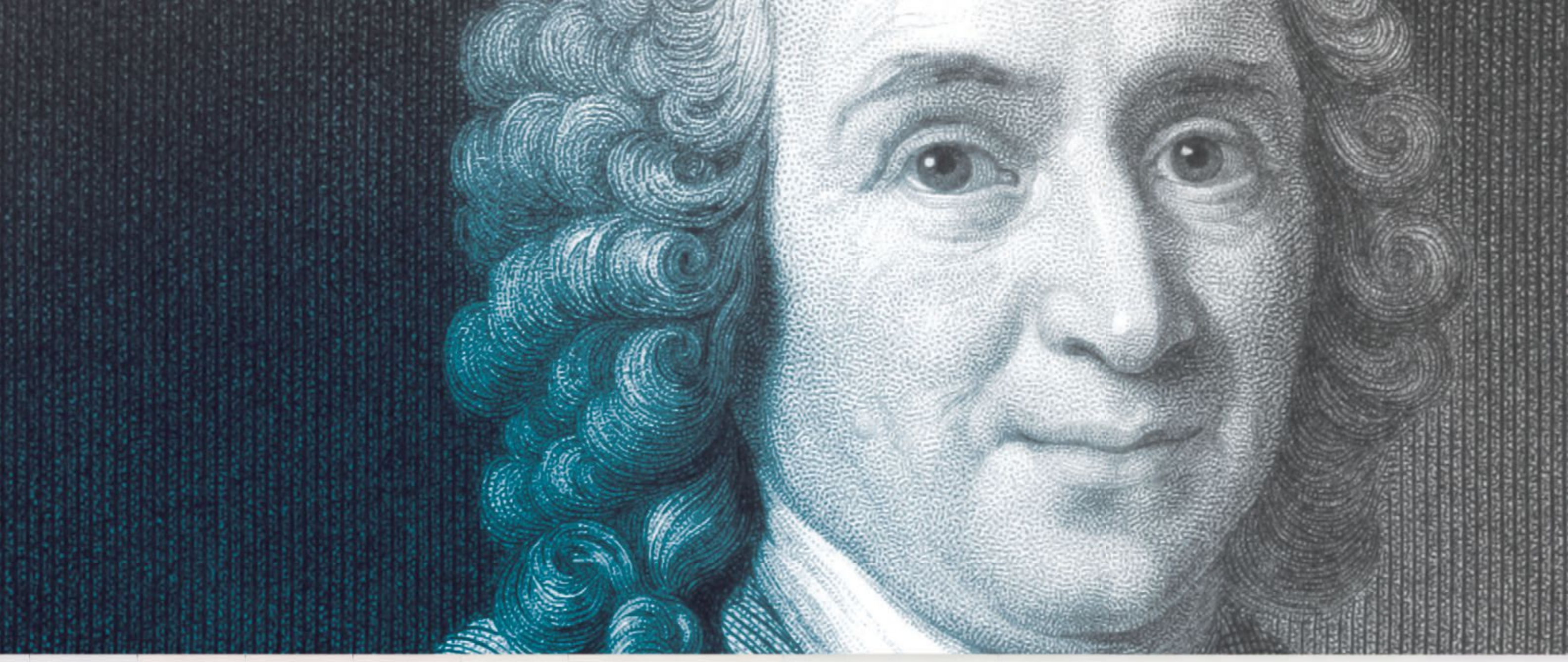

CLASSIFICATION

Putting everything in its place

Renee Clary and James Wandersee

Classification lies at the very heart of science. Even a multitude of data cannot advance the discipline until appropriately organized and analyzed. Geologists developed the geologic time scale to divide Earth's 4.6-billion-year history; chemists use a periodic table to consolidate the properties of elements; and paleontologists and biologists employ taxonomy and cladistics to identify and determine relationships among extinct and living organisms.

Classification depends upon pattern recognition, one of the crosscutting concepts of the *Next Generation Science Standards* (NGSS Lead States 2013), based on *A Framework for K–12 Science Education* (NRC 2012). Our natural world tends toward *disorder,* so recognizing a pattern can be "the first step to organizing phenomena and asking scientific questions about why and how the patterns occur" (NRC 2012, p. 85). Classification systems can evolve as the scale of observation changes and more scientific information and detail are uncovered. This evolution reflects the nature of science (NOS), since the NOS Matrix includes "Scientific Knowledge Is Open to Revision in Light of New Evidence" and "Science is a Human Endeavor" (NRC 2012). Historical case studies illustrate these characteristics of the nature

FIGURE 1

Linnaeus' garden home at Uppsala functioned not only as the family's home but also as a scientific center.

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of science and also fascinate our students (Clary, Wandersee, and Carpinelli 2008; Clary and Wandersee 2011). Accordingly, we approach patterns by first telling the story of the Linnaean classification system, *before* students undertake activities to find patterns and develop—and justify—their own classification systems.

Linnaeus: Observation and classification

Carl Linnaeus (1707–1778; portrait, p. 31), known as the father of taxonomy and a founder of ecology, is credited with devising the formal system for naming species. He introduced the *binomen,* or "Latin name" system, identifying an organism with a genus name and, within the genus, a species name. Species, the most exclusive category of classification, are those organisms with similar morphologies that can interbreed and produce fertile offspring. For example, *Panthera tigris* is the binomen for the tiger: *Panthera* identifies the cat genus, which also includes the leopard and the lion, and *tigris* the particular species of cat. Linnaeus first applied this system of nomenclature to plants, thereby revolutionizing botany and founding plant taxonomy. Later, he applied it to animals as well.

We researched this pioneering scientist through historiographic methods (Howell and Prevenier 2001), including visits to Linnaeus's university, garden, home, and farm in Sweden, and by studying his work through historical documents and artifacts. Introducing students to Linnaeus and the history of classification piques students' interest in the nature of science and the way science progresses (Matthews 1994).

Observational beginnings.

Carl Linnaeus, nicknamed the Little Botanist at school, acquired his passion for plants from his father, Nils, a minister and amateur gardener. Nils decorated his son's crib with flowering plants, and when the baby seemed unhappy, gave him a flower to play with. At age four, Carl was reportedly impressed by his father's remarks about the uses of neighborhood plants in their community of Rashult in southern Sweden. His father taught him plant names but, after young Carl forgot some of the names, warned he would stop teaching him if this continued. So Carl redoubled his efforts to learn about plants, beginning his habit of careful observation and attention to detail. Ultimately, Linnaeus would name about 12,000 of the world's plants over his lifetime.

Integrated investigations

Linnaeus became a professor at Uppsala University in the Swedish town of Uppsala. He was popular with students, largely due to his great enthusiasm and novel ways of teaching. He didn't confine his research to a university laboratory. At his home (Figure 1), located next to a large teaching and research garden, the ground floor served as family living quarters, while the upstairs was devoted to a scientific center with lecture room, library, study, and rooms for botanical collections. The garden (Figure 2) was the first botanical garden of Sweden, founded not by Linnaeus but by Olof Rudbeck the Elder in 1655. In 1741, Linnaeus took over the garden and then rearranged it. Today about 1,300 plant species are grown here, all of which were once cultivated by Linnaeus and arranged according to his system. Linnaeus always carefully organized

FIGURE 2

Linnaeus's teaching and research garden today still includes plants that Linnaeus cultivated. The plants are arranged according to Linnaeus' own system.

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new findings and observations: His books are interleaved and copiously annotated. Thus, observation, organization, and categorization were key to his scientific botanical approach.

Teaching observation

Teaching his students how to observe nature outdoors was central to Linnaeus's methods. He arranged various daylong natural history excursions around Uppsala. These popular excursions, called the *Herbationes Upsalienses,* attracted students by the hundreds (Blunt 2004). Accompanied by musicians, Linnaeus and his companions would collect plants and relevant animals and minerals. Linnaeus demonstrated his skills and mobilized support during this open-air class, which was also a testing, training, and recruitment ground: The students' field observations helped Linnaeus develop his new scientific nomenclature, while the students honed their observational skills and progressed from novices to naturalists.

Many of his students later joined important scientific expeditions to far-off lands. They sent their former professor exotic new species of plants and animals, which he used when he published his binomial system of assigning Latin names to plants (1753) and then animals (1758) (Reveal and Pringle 1993; Simpson 1961). Linnaeus developed the classic hierarchy that eventually evolved to include kingdom, phylum, class, order, family, genus, and species. His students helped disperse his nomenclature and taxonomy.

FIGURE 3

Fasteners form the basis of our "fastenetios" classification activity. They come in many forms, such as these clips (battery shows scale).

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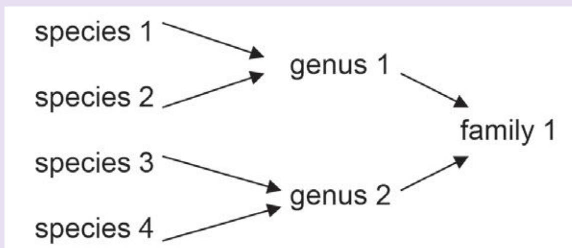
FIGURE 4

Organizing species into genera and genera into a family will help students identify broader characteristics linking the larger classification divisions.



Linnaeus and the nature of science

Not all of Linnaeus's findings have held up. Over time, other scientists have refined his classification schemes. His story reveals how classic taxonomy originated and was corrected and reorganized as new data and methods emerged (Duschl 1994). Despite these corrections, Linnaeus is still honored for having first enunciated modern taxonomic principles. For him, clarity was paramount: He communicated succinctly and with a consistent term for each plant part, or organ.

Scientists no longer rely heavily on Linnaean classification, preferring the cladistics classification based on shared characteristics among taxa. New DNA and other molecular evidence have allowed scientists to recognize patterns indicating evolutionary relationships. However, the Linnaean binomen is still the basis for identifying and naming new species, with international rules now governing the process.

The story of Linnaeus can be incorporated into the classroom as a teacher-led discussion, group research project, or brief Interactive Historical Vignettes (Clary and Wandersee 2006, Wandersee and Clary 2006), depending upon available classroom time and teacher preferences.

The fastenetios activity

Following the Linnaean history, we suggest that students apply pattern recognition and classification in the development of a taxonomic hierarchy. We use a classification activity involving a variety of paper fasteners, which we collectively call fastenetios. These fasteners are widely available, come in a variety of styles, and are inexpensive. The activity can be done in any season (unlike leaf or plant classification activities).

To start, purchase paper clips of various types, shapes, and compositions (e.g., plastic, metal), and other paper fastening devices such as binder clips (Figure 3, p. 33). Assemble random collections of the objects in plastic sandwich bags.

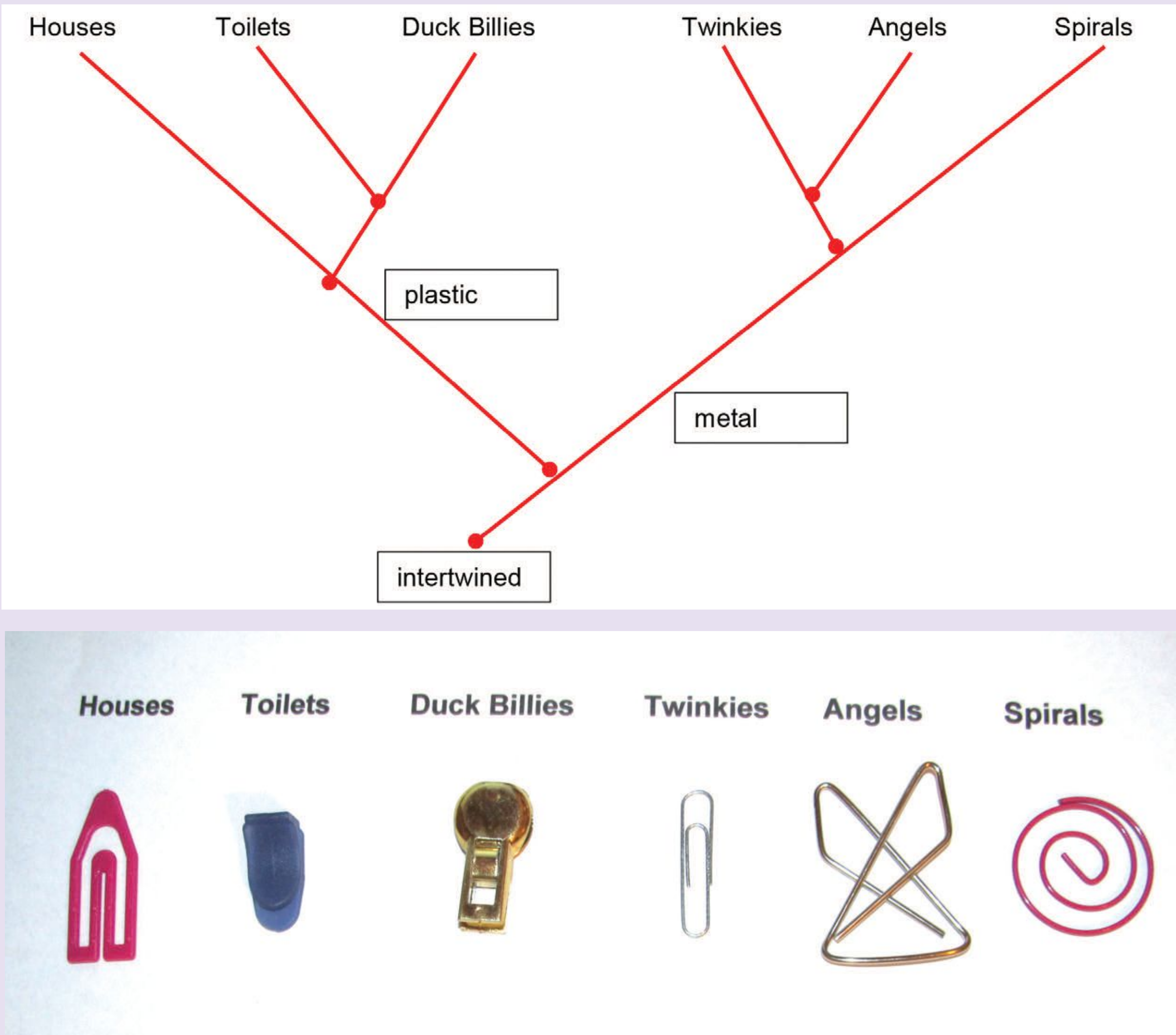
Assign students to small groups (two to four students each) and provide each group with a bag of fastenetios. Students must use their observation skills to find patterns among their fastenetios. (For activity handouts, see "On the web.")

Part 1: Determining categories.

Groups should first divide their bag of fastenetios into categories. Groups must determine how many categories they need to effectively organize their specimens. For each category, students should prepare a sketch, a description of category characteristics, and a justification for the category. Near the end of the class period, each group presents its classification scheme, justifying the categories and identifying each category's discriminating characteristics. Groups argue and defend their schemes. The class votes on the best classification scheme after all groups present.

FIGURE 5

Sample student-produced cladogram. The students chose species names based on familiar objects that resembled the paper fasteners.



Part 2: Comparing species and Linnaean classification.

On the second project day, student groups discuss how their classification activity compares with the modern version of Linnaeus's classification schemes. Groups also determine whether their categories in Part 1 could represent species of fastenetio organisms. Students next investigate taxonomic hierarchies, including order, family, and genus. Groups first determine whether their fastenetios represent a single organism's remains or the disarticulated parts of an organism or organisms. Each group composes a brief list of the characteristics they used to classify fastenetios into *species* and a list of characteristics that connect species within each *genus* and genera within a *family* (Figure 4, p. 33). Students are searching for patterns that unite their categories (species) into broader genus categories, and then patterns that unite their broader genus categories into family categories.

Students finish by constructing a *cladogram*—a diagram

FIGURE 6

Rubric for scoring group classification projects. Replication of classification schemes based on group project descriptions is optional.

CATEGORY	4	3	2	1
Scientific concepts	Project illustrates an accurate and thorough understanding of scientific classification concepts.	Project illustrates an accurate understanding of most scientific classification concepts.	Project illustrates a limited understanding of scientific classification concepts.	Project illustrates an inaccurate understanding of scientific classification concepts.
Drawings/ Diagrams	Clear, accurate diagrams represent the fastenetios. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
Classification schemes	Classification schemes are listed in clear steps. Each step is numbered and is a complete sentence.	Classification schemes are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Classification schemes are listed but are not in a logical order or are difficult to follow.	Classification schemes do not accurately reflect the fastenetios.
Analysis	The relationship between the fastenetios is discussed and trends/patterns logically analyzed. Predictions are made about how additional information would affect the results.	The relationship between the fastenetios is discussed and trends/patterns logically analyzed.	The relationship between the fastenetios is discussed, but no patterns, trends or predictions are made based on the data.	The relationship between the fastenetios is not discussed.
Replicability	Procedures appear to be replicable. Steps are outlined sequentially and are adequately detailed.	Procedures appear to be replicable. Steps are outlined and are adequately detailed.	All steps are outlined, but there is not enough detail to replicate procedures.	Several steps are not outlined, AND there is not enough detail to replicate procedures.

that illustrates the shared characteristics among their groups of fastenetios. First, students decide which characteristics of their categories evolved first and are primitive *(plesiomorphic)* and which evolved later and are advanced or derived *(apomorphic)*. For example, a primitive characteristic might be that fastenetios exhibit one interior coil. Advanced characteristics might be the external shape, thickness, and additional coils of the fastenetio. Students may creatively reconstruct a possible body form for the fastenetio organisms, which experienced evolutionary changes over time. (Figure 5, p. 34, shows a student example.)

Final group product

As an in-class activity or a homework extension, groups should summarize their classification scheme into a presentation booklet that includes:

- species descriptions with labeled sketches and organism descriptions,
- a taxonomic hierarchy, and
- a cladogram.

If time permits, group projects can be exchanged for analysis, in which the analyzing group uses only the information provided by the original group to organize the contents of the fastenetio bag. Therefore, groups field-test their colleagues' descriptions and cladograms. The sample rubric in Figure 6, page 35, can help you score the final projects.

Alignment of patterns with *NGSS*

In the *Next Generation Science Standards* (NGSS Lead States 2013), the crosscutting concept of patterns aligns with HS-LS4: Biological Evolution: Unity and Diversity, and the performance expectation (PE) that students will "communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence" (HS-LS4-1).

Our classification activity can also be extended to address additional disciplinary core ideas of the *NGSS* for both Life Science and Earth and Space Science (see "On the web"). In Life Science, classification can extend into the PE HS-LS4-4, where students are required to construct an explanation of how natural selection may have influenced the acquisition of characteristics in their fastenetio population. Alternatively, the Earth science PE HS-ESS2-7 can be addressed by requiring students to hypothesize the geoscience factors that may have accompanied and been responsible for the population changes of their fastenetios over time.

Conclusion

The crosscutting concept of pattern recognition is important in all scientific disciplines. Classification activities such as the one in this article develop student observation and organization skills, fostering a more scientific frame of mind. Similarly, teaching the history of classification helps our students appreciate the human side of science and understand that science evolves with new information (Jenkins 1989). We encourage our colleagues to try these classification investigations in their own classrooms. ■

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On the web

Student activity handout and extension: *www.nsta.org/highschool/connections.aspx*

References

Blunt, W. 2004. *Linnaeus: the compleat naturalist*. London: Frances Lincoln.

Clary, R.M., and J.H. Wandersee. 2006. Mary Anning: She's more than "seller of sea shells at the seashore." *The American Biology Teacher* 139 (3): 153–157.

Clary, R.M., and J.H. Wandersee. 2011. A coprolite mystery: Who DUNG it? *Science Scope* 34 (7): 32–42.

Clary, R.M., J.H. Wandersee, and A. Carpinelli. 2008. The great dinosaur feud: Science against all odds. *Science Scope* 32 (2): 34–40.

Duschl, R.A. 1994. Research on the history and philosophy of science. In *Handbook of research on science teaching and learning*, ed. D.L. Gabel, 443–65. New York: Macmillan.

Howell, M., and W. Prevenier. 2001. *From reliable sources: An introduction to historical methods.* Ithaca, NY: Cornell University Press.

Jenkins, E. 1989. Why the history of science? In *Teaching the history of science*, eds. M. Shortland and A. Warwick, 19–29. Oxford, England: Basil Blackwell.

Matthews, M.R. 1994. *Science teaching: The role of history and philosophy of science*. New York: Routledge.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

Reveal, J.L., and J.S. Pringle. 1993. *Flora of North America.* Oxford, England: Oxford University Press.

Simpson, G. 1961. *Principles of animal taxonomy*. New York: Columbia University Press.

Wandersee, J.H., and R.M. Clary. 2006. Interactive historical vignette: The scientific endeavors of Mary Anning, the first woman paleontologist. In *Teaching and learning science: A handbook,* ed. K. Tobin, 283–290. Westport, Connecticut: Praeger.