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Understanding evolution through close observation of specimens: A multi-lab experience

Robin Hulbert and Sandra Buerger

Boston University, College of General Studies, Division of Natural Sciences and Mathematics, 871 Commonwealth Ave, Boston, MA 02215 USA

Extended Abstract

Students in introductory biology courses often struggle to visualize and understand the process of evolution in complex organisms. The slow and gradual nature of evolution makes it challenging to design laboratory activities that allow for direct observations of evolutionary change, especially in higher taxonomic groups. Our department has designed and refined a set of labs involving direct specimen observations and cladogram construction in order to help students (mostly non-Biology majors) in an introductory Ecology and Evolution course understand the process of evolution. These lab activities allow the students to view both extant and extinct species, visualizing structural similarities and differences first-hand. Groups of specimens include flowers from extant angiosperms, extant vertebrate skeletons, fossils of extinct plants and animals, and skulls of extinct and extant hominids. Faculty teaching the course can select the sets of specimens that work best for their individual approach.

In each of the labs, students observe the specimens closely while working in a group. With guidance from the instructor, students select physical traits that are evolutionarily significant. These traits are described and quantified, then mapped onto a similarity matrix. The students use their observations to build cladograms showing possible evolutionary relationships. Through this close observation and cladogram building, they are able to directly observe evolutionary similarities and differences between species from disparate taxonomic groups. In addition, the students learn about the pitfalls and limitations of morphological observations in determining evolutionary relationships. The ability to repeat the process using different specimens allows students to hone their skills in taxonomic analysis. By the time students reach the final lab (hominid skulls), they are able to independently identify characteristics that are evolutionary significant, measure relative traits appropriately, and are adept at building cladograms. In our experience, students find this set of labs very engaging. They are able to visualize evolutionary change while applying concepts previously learned in lecture.

The final lab in the series involves looking at hominid skulls- these include the skulls of extant members of the Great Apes, along with casts of extinct hominin specimens. Due to the close evolutionary relationships between these specimens, students are required to use skills acquired over the semester and apply what they learned in earlier labs to determine which traits are evolutionarily significant. The students select from a variety of specimens and features to observe. Examples of traits that students commonly choose to observe include presence of a diastema, slope of the face, presence of a brow ridge, differences in dentition, cranial capacity, and position of the foramen magnum. With instructor guidance they make measurements and observations about the features and weigh the evolutionary significance of these features.

In addition to the cladogram and similarity matrix, student assignments for these labs include a discussion of the traits that distinguish each clade, addressing which characters are shared-derived versus shared-primitive. Students also describe issues they encountered during the lab, their confidence level in their hypothesis (cladogram), and two additional types of studies that could corroborate or falsify their hypothesis.

At the conclusion of this lab series, students have made notable progress in understanding evolutionary concepts, as well as shown marked improvement in their ability to construct accurate cladograms *based on observation.* The average score on later labs in the series was higher than the earlier labs in both 2021 and 2022, suggesting that students did improve.

While the cladograms do not always represent the evolutionary relationships that are supported by a mix of morphological and molecular data, the students *are* able to draw direct lines between their observations and their hypothesized relationships. Further, the students are able to distinguish between shared primitive and shared derived traits, as well as recognize the limitations in drawing evolutionary conclusions from morphological observations. Through these repeated experiences, students gain a deeper understanding of the processes that shape evolutionary change.

Keywords: evolution, phylogeny, homology

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Correspondence to: Robin Hulbert and Sandra Buerger, rhulbert@bu.edu, sbuerger@bu.edu

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