



Understanding Evolution Through Close Observation of Specimens: A Multi-Lab Experience

Robin Hulbert and Sandra Buerger

Boston University, College of General Studies, Natural Sciences and Mathematics

Abstract

Undergraduate 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. In order to help students understand these difficult concepts, our department has designed and refined a set of labs involving direct specimen observations and cladogram construction. 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 hominins. 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 (hominin skulls), they are able to independently identify characteristics that are evolutionarily 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.

Example Student Assignment

Character Matrix							
	Perch (outgroup)	Alligator	Turtle	Frog	Platypus	Armadillo	Opossum
Presence of Lungs	yes	yes	yes	yes	yes	yes	yes
Presence of Gills	no	yes	yes	yes	yes	yes	yes
Presence of Claws	no	no	no	yes	yes	yes	yes
Presence of Fingers	no	no	no	yes	yes	yes	yes
Presence of Toes	no	no	no	yes	yes	yes	yes
Presence of Nails	no	no	no	yes	yes	yes	yes
Presence of Horns	no	no	no	yes	yes	yes	yes
Presence of Hooves	no	no	no	yes	yes	yes	yes
Presence of Wings	no	no	no	yes	yes	yes	yes
Presence of Tail	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes
Presence of Crown	no	yes	yes	yes	yes	yes	yes
Presence of Neck	no	yes	yes	yes	yes	yes	yes
Presence of Skull	no	yes	yes	yes	yes	yes	yes
Presence of Jaw	no	yes	yes	yes	yes	yes	yes
Presence of Teeth	no	yes	yes	yes	yes	yes	yes
Presence of Molars	no	yes	yes	yes	yes	yes	yes
Presence of Incisors	no	yes	yes	yes	yes	yes	yes
Presence of Canines	no	yes	yes	yes	yes	yes	yes
Presence of Premolars	no	yes	yes	yes	yes	yes	yes
Presence of Pulp	no	yes	yes	yes	yes	yes	yes
Presence of Root	no	yes	yes	yes	yes	yes	yes</