

Tackling Phylogeny in Introductory Biology Laboratories

*Marianne Niedzlek-Feaver and
John W. Zimmerman*

Marianne Niedzlek-Feaver
Box 7617 Zoology
North Carolina State University
Raleigh, NC 27695-7617
919-515-9051
Fax 919-515-7519
Email:mnfeaver@unity.ncsu.edu

John W. Zimmerman
Science Division
400 N. Bluff Blvd.
Mount St. Clare College
Clinton IA 52732
319-242-4257 x2230
Fax 319-242-2003.
Email:johzim@clare.edu

Marianne Niedzlek-Feaver is an Associate Professor of Zoology at North Carolina State University, where she teaches general biology and evolution. She received her BS and MS in Biology from the University of Illinois and her PhD in Zoology from the University of Michigan.

John W. Zimmerman, PhD in Zoology, has been teaching undergraduate introductory biology courses for 14 years. John received his Ph.D. from and has taught at North Carolina State University. Currently he is the Chair of the Science Division at Mount St. Clare College, Clinton, Iowa.

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Introduction

In looking over course evaluations, we have often found students rank traditional phylogeny laboratories low. Students feel such labs are exercises in memorization for later regurgitation of numerous facts about dead subjects often encased in cloudy specimen jars. Students are frustrated because they feel they lack the background to truly appreciate the trends and relationships inherent in the diversity before them. Even when a laboratory about taxonomy is presented as the capstone experience, the amount of information that students traditionally must assimilate is usually large and so adds to student dissatisfaction. More importantly, the activities involved are often some of the most passive, and so perceived uninteresting, in the course.

We have made an effort to make learning about phylogeny a more worthwhile if not a more pleasant experience by disseminating the information over a number of laboratories and including as much hands-on and other active learning experiences in our named “phylogeny” laboratory. We feel we have been most successful, as this laboratory has become one of the student’s favorites; consistently over the last five years ranked among the top three. In a laboratory schedule that includes laboratories devoted to such timely and frankly more “sexy” activities such as DNA fingerprinting, this is no small accomplishment.

Our introductory biology course is one that draws not only life science majors, but also majors from commodity departments (such as animal science and nutrition) as well as allied science departments such as chemistry, physics, and engineering. Although non-science majors are discouraged from taking the course we also draw about 1/3 of our students from the humanities and social sciences. The course is taught from an evolutionary perspective and evolutionary theory is treated early, weeks two and three, in the course. The first three laboratories contain natural selection activities in addition to more traditional topics such as enzyme activity. Material on phylogeny is formally integrated into several laboratories, actually four of the twelve true laboratories (14 meetings minus an introduction and student presentation period) in this one semester introductory biology course.

For example, one third of the material presented in our Cells laboratory is a survey of the five kingdoms for the “types” of cells found in each. It includes then a formal introduction to the idea of kingdoms. Some discussion of the different schemes used (a two-kingdom system and one involving domains) is also given in lecture. We emphasize differences among the kingdoms students can see, for example, cell size in prokaryotes as opposed to eukaryotes, and cell specialization in plant and animal cells. These types of differences are also addressed in lecture at the same time. Our first inheritance laboratory (primarily concerned with mitosis and meiosis) adds information on the differences in life cycles in three kingdoms, Fungi, Plantae and Animalia. After the animal classification laboratory, a laboratory on development and reproduction treats evolutionary trends in the plant kingdom.

The Animal Classification Laboratory

Our named phylogeny laboratory surveys the animal kingdom because students are most familiar with common characteristics in this group. Our diverse audience also is interested in

learning more details about this kingdom than other kingdoms. We list three objectives for this laboratory.

1. To experience classification as a dynamic and worthwhile activity
2. To appreciate evolutionary trends in the animal kingdom
3. To become more familiar with invertebrates

To accomplish these objectives we provide activities in which students themselves determine the characteristics to be used in assessing relationships. Students are also asked to rank the relationship or tree of those possible that best fits the data they have generated. Given that we restrict the possible characteristics (particularly with the more unfamiliar invertebrate phyla) to those that students can readily observe in the laboratory, we have turned potentially passive activities into interactive discovery experiences.

Activities

Students are first introduced to the general scheme they will use to assess relationships. Students are to assume all characters initially have the same value. They are presented with four imaginary “bugs” and a table similar to ones they will construct listing “characteristics” for these creatures. Then they are introduced to all the possible relationships that could exist between these four animals and how to represent them. An excerpt from the laboratory manual that covers this introduction follows.

An Example

We have four groups of organisms labeled A, B, C, and D. First, we make a list of the characteristics shared by at least two groups. Then we make a table using our four groups as column headings and the different characteristics as rows. We fill in the table, indicating who has what characteristic.

	A.	B.	C	D
				
Characteristic	A	B	C	D
legs	2	4	2	0
head	yes	yes	yes	no
eyes	2	no	2	no
tail	yes	no	yes	no
stripes	no	yes	yes	yes

Figure 1. Characteristics of four related imaginary organisms.

With four groups only two different relationships are possible:

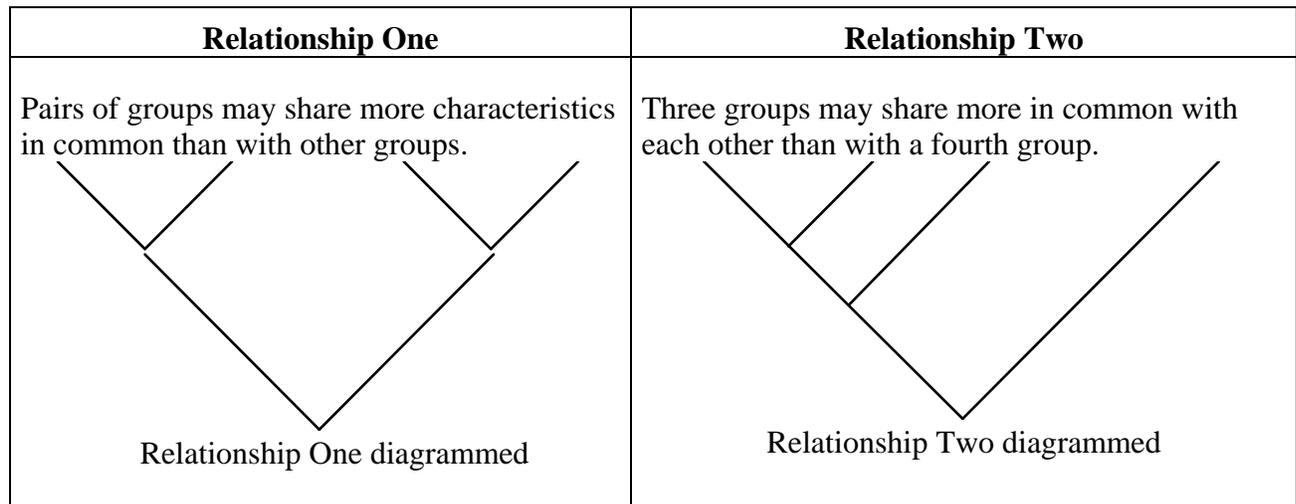


Figure 2. The two possible relationships that can exist when only four groups related in some way are considered.

How would you determine which relationship was the more correct depiction of shared characteristics? The simplest way is to choose the relationship scheme that explains the greatest numbers of characteristics shared by at least two groups.

Let us assume we are dealing with Relationship One, which is two groups more related to each other than to other groups and the two remaining groups are also more related to each other than to the other groups. (But we don't know which groups are more related to which.) Let's redraw that relationship One diagram, leaving room to note which characteristics are explained by the depicted relationship. We'll place the number of the characteristics explained in circles drawn where we have joined lines representing two groups.

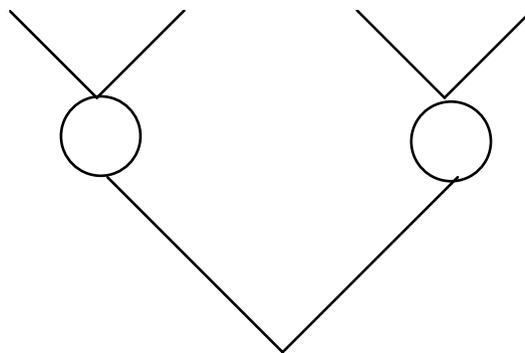


Figure 3. Relationship One drawn with circles at junctions.

Now let us explore which groups should be placed together. First we will try them as listed, A & B, C & D. Then, we'll group A & C, B & D. Finally, we'll group A & D, B & C. For each possibility, we will place the number of shared characteristics by the two in the circle joining the two groups. Note our second grouping is the best representation of how similarities are distributed among the four groups, at least for Relationship One.

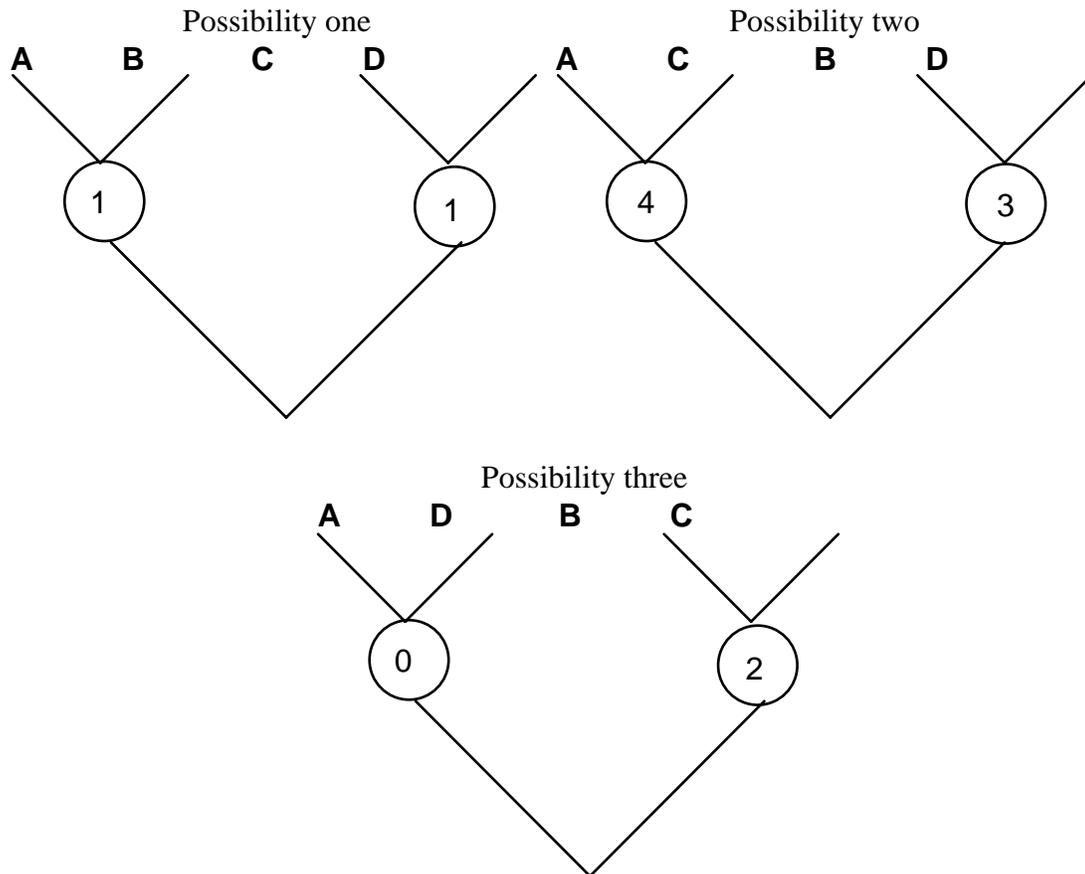


Figure 4. The possibilities for Relationship One.

The same can be done for Relationship Two. However, there are 12 possible ways to distribute four groups using Relationship Two. See the diagram below. Consult your laboratory instructor if you do not understand how the 12 different groupings for Relationship Two were derived.

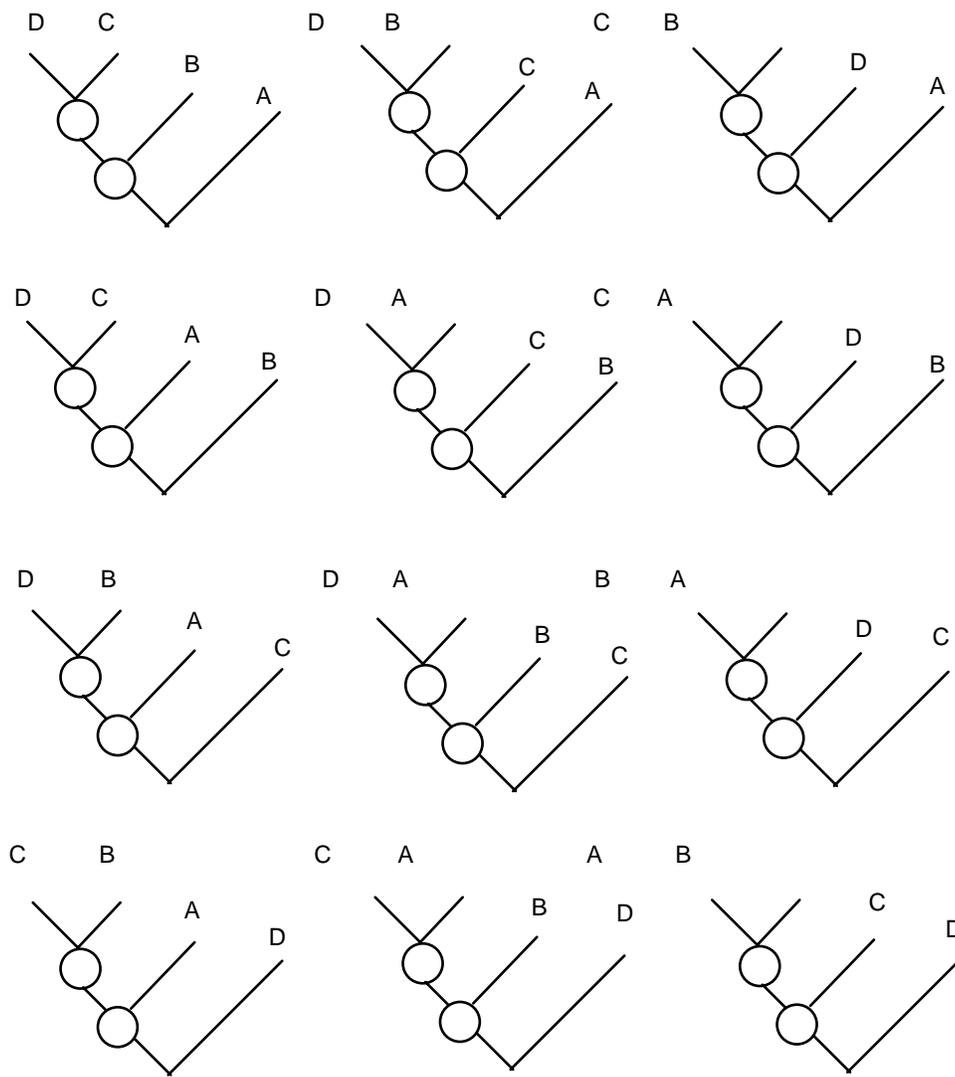


Figure 5. The possibilities for Relationship Two.

The Vertebrates

Students are then assigned four vertebrate classes to classify. In different semesters we have used different classes and different numbers of classes, although any one group of students only compares four classes so that they can explore all possible relationships. Most recently, this laboratory has been used early in the schedule and the emphasis has been then on gaining familiarity with invertebrate phyla. The vertebrate exercise has been shortened to be a class exercise on gaining experience with the scheme to be used, and reviewing facts learned about vertebrates in lecture before tackling the invertebrates. We then have assigned the whole class AVES, AMPHIBIA, MAMMALIA and REPTILIA. Each group of students fills out the table, which adds characteristics students can observe in the laboratory to those treated in lecture such as mode of temperature regulation or the excretory product typifying the group. Some skeletal

characteristics are used, because of their commonness in the fossil record. *The major criteria are that students can readily observe the characters in the material provided.* The laboratory manual contains a short description of all characteristics students routinely use.

Students discuss and then vote on which characteristics to use for the various vertebrate classes. For example, since a variety of reptilian skulls are available to students, they need to decide if the turtle skull, alligator skull, or model tuatara skull should represent the norm for the class Reptilia. Or they need to decide if the way skull type is defined should take into consideration that all three types of skull can be found in this class.

Skull type: In the vertebrate line, skulls have become less flat, and additional "openings" to allow jaw muscles to pass through before attaching to the top of the skull are found. This gives more room for jaw muscles and allows for more jawbone elaboration. Vertebrates are classified as:

anapsid: no additional opening in position indicated on lab table displays, right behind eye openings;

synapsid: one additional opening in position indicated on lab table displays;

diapsid: two additional openings in positions indicated on lab table displays.



Because the openings have been modified in most extant species, the number is difficult to quantify. You may wish to classify groups as having broad skulls with evidence of jaw muscle attachment sites in proper positions or flat skulls with no evidence of attachment sites. One of the biggest problems in comparing groups is trying to determine "what constitutes a meaningful characteristic". Just remember if you construct a characteristic, such as extra holes or none, apply it the same way every time you assess relationships.

Figure 6. Example of a description given in the lab manual for a character.

This is a good time to discuss character weighting. Should one character, such as mode of reproduction, be assigned a higher point value than another character such as skull type? Laboratory instructors report lively debates among students concerning the relative importance of different characters.

Each table (group of four students) is then assigned three trees or relationships of the 15 possible to examine (see Figures 3 and 4). They enter their numbers on a transparency for the whole class so that the class can easily observe which relationship best fits the characters chosen. Often I discuss in lecture any discrepancies noted among laboratory sections in judgment regarding best relationship. It is not uncommon for one laboratory section to have determined that amphibians and reptiles are more closely related to each other than they are to mammal and birds (Relationship One) only to have another section determine that amphibians, birds and reptiles are more closely related to one another than they are to mammals (Relationship Two).

If time permits, often the laboratory instructor will let the students compare weighted with unweighted relationships or use different character tables to build relationships to illustrate further classification as a dynamic activity. When this laboratory is the last in the schedule, we often devote more time to this section. We will allow different student groups to do different vertebrate classes or we will allow each table to use different characters and different numbers of characters to build their relationships. Each student group then has to justify their approach to the rest of the students in that laboratory section. Recently we have placed references in the laboratories for student use, so they can add and later discuss the validity of adding behavioral or ecological characters.

Invertebrates

Once students are familiar with building all possible trees using four vertebrate classes, so only a reasonable number of trees are possible, they apply the method to become more familiar with invertebrate phyla. With the invertebrates they commonly use only those characters they can observe in the laboratory. We do provide a demonstration using live material on locomotionary trends in animals to introduce them to structures of importance. Typically, students would score easily observed characteristics such as presence or absence of a coelom (judged by animal “thickness”), presence or absence of a skeleton and type of skeleton (exo or endo) present, type of symmetry observed, and presence or absence of appendages and whether appendages are jointed. We also have CDs available that students can use for reference that supplement the living material with animations of muscle and joint movement, and show different animals moving through various media. Instructors encourage debate and exploration of reference material, although the characters students can observe in specimens found on the laboratory table are emphasized. Generally each group of students compares three different invertebrate phyla to Arthropoda. As students fill out tables and trees they apply what they are learning from the demonstration and specimens found on the laboratory tables. The hope is that students are left with an impression of taxonomy as a dynamic and challenging discipline, subject to critical testing, as any other discipline in biology.

SOLUTION ONE: THE HYDROSTATIC SKELETON

This is probably the first type of skeleton utilized in locomotion. Annelid worms are excellent examples of a hydrostatic skeleton in the form of a coelom in action. In earthworms, sheaths of longitudinal and circular muscles surround the hydrostatic skeleton or coelom. When the longitudinals shorten a short fat animal is produced, when the circulars contract, a long thin one.

Locomotion begins with a contraction of the circular muscles in a limited region of the anterior end of the body. This contraction passes backwards down the body as a wave, each wave of circular contraction being followed by a wave of contraction of the longitudinal muscle. At those regions where the longitudinal muscle is contracting the body surface bulges outwards and the setae are protruded. At these points, the worm can exert a thrust against the substratum. Where the circular muscle is contracting the body becomes thinner, and the setae are withdrawn. Here the segments extend forward, aided by the thrust from the swollen regions. Thus the extension of the thinner parts of the body can be translated into forward movement. Waves of this sort can be used to drive the animal along and if, as in earthworms, some form of anti-slip device is incorporated into the design, considerable forward pressure can be generated.

Placing the worm on a glass plate can show the importance of the thrust against something like a burrow wall and the anti-slip device. Although the hydrostatic skeleton again gives effective movement in a viscous media (a burrow for earthworms, water for other organisms with hydrostatic skeletons), it proves ineffective for true forward locomotion on land.

Compare how your earthworm moves when placed in the center of a metal pan lined with a 1/4 inch layer of moist dirt and an unlined metal pan.

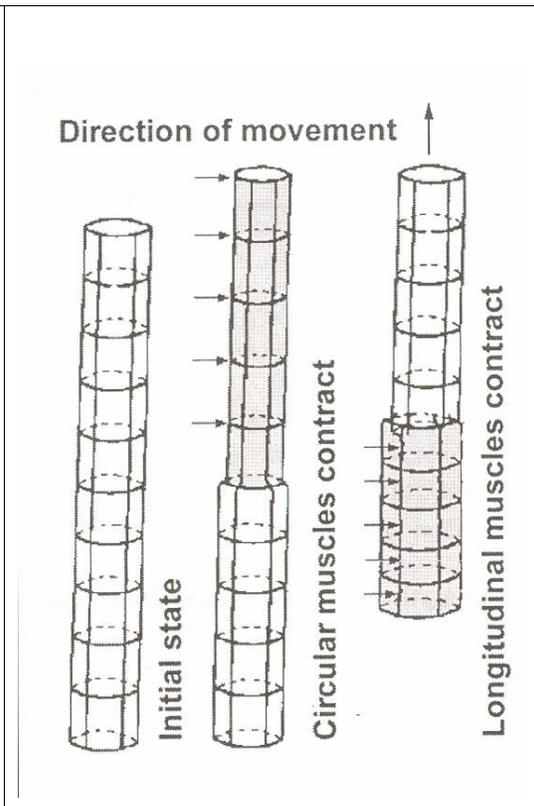


Figure 7. An excerpt from the demonstration on locomotionary trends in the animal kingdom. Several diagrams have already defined the term coelom and setae for students

For More Information

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