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Construction of Phylogenetic Trees in a Non-Majors Biology Laboratory as a Means of Teaching Biodiversity

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One of the challenges in teaching biology to non-science majors is the topic of biodiversity. Students try to remember facts about each organism, major division or phyla presented to them. They do not try to make connections and see evolutionary relationships between different groups of organisms. We have developed a laboratory exercise where students complete a phylogenetic tree encompassing the organisms they encounter in class. In this workshop, participants will work through trying to complete the missing components of the tree. Discussion of how an assignment of this nature can be adapted to any biology course will also be addressed.

Keywords: Non-Science Majors; Biodiversity, Phylogenetic Tree

Link to Supplemental files: http://www.ableweb.org/volumes/vol-36/forster/supplement/htm

Introduction

In Spring 2011, Saint Joseph's University developed laboratory-based science courses as part of the school's general education program. These courses follow the objectives outlined in *Science for All Americans* (Rutherford & Ahlgren, 1991) and are designed specifically for non-science majors. One such course is "Exploring the Living World" (Biology 165). In Biology 165, students learn about the scientific worldview with respect to the natural world. All levels of biological organization are covered, from atoms up to ecosystems. The course covers topics such as cell structure, energy in the cell, the cell cycle, Mendelian and molecular genetics, plant and animal physiology, and evolution. Within the discussion of evolution, the students are introduced to a phylogenetic tree as a tool of evolutionary biologists and learn that it can be used to examine diversity of life (Julius and Schoenfuss, 2006). The tree of life is then shown to the students.

Using the knowledge gained from each of these topics, students begin a one-month unit on the biodiversity found on Earth. In the laboratory, students work through four biodiversity labs. These labs include prokaryotic diversity, protist diversity, plant & fungal diversity and animal diversity. Including the organisms that are presented in lecture, the students encounter over 30 different organisms during this unit. It is important to teach this topic to non-science majors such that students become scientifically-literate individuals that can see the biological, environmental and economic importance of biodiversity (McCoy *et al*., 2007).

We observed that our students had great difficulty grasping concepts from this particular unit of the course. Students treat each organism as a separate entity without considering similarities between that organism and others. In terms of the tree of life, students focus on individual branches and forget to look at the whole tree. As a result, the student becomes overwhelmed and disengaged in the learning process. It has been suggested that an additional difficulty in teaching biodiversity lies in the fact that the classroom is not the ideal location to teach such a topic (Zervanos and McLaughlin, 2003). An ideal location would be through field trips.

To address these concerns and difficulties of teaching biodiversity, we have developed a laboratory-based exercise where students fill in a phylogenetic tree encompassing the organisms they encounter both in the lecture and laboratory. This activity is assigned in conjunction with our biodiversity laboratories covering prokaryotes and the four kingdoms of Domain Eukarya. The workshop that was presented allowed participants to examine our tree and work through identifying some of the features of the tree. The workshop ended with a brief discussion of the feedback that students have provided the authors about the assignment and how such an assignment can be adapted into any lecture and/or laboratory.

Student Outline

Background Information

Life can be classified into one of three domains (Archaea, Bacteria and Eukarya). Within the Eukarya domain are four kingdoms (Protist, Fungi, Plant, Animal). Figure 1 below shows the general properties of each of these domains and the kingdoms.

Having an understanding of the sizes of organisms, cell functions and evolution, you will now begin to explore the diversity of life on earth by observing representatives from each of these divisions.

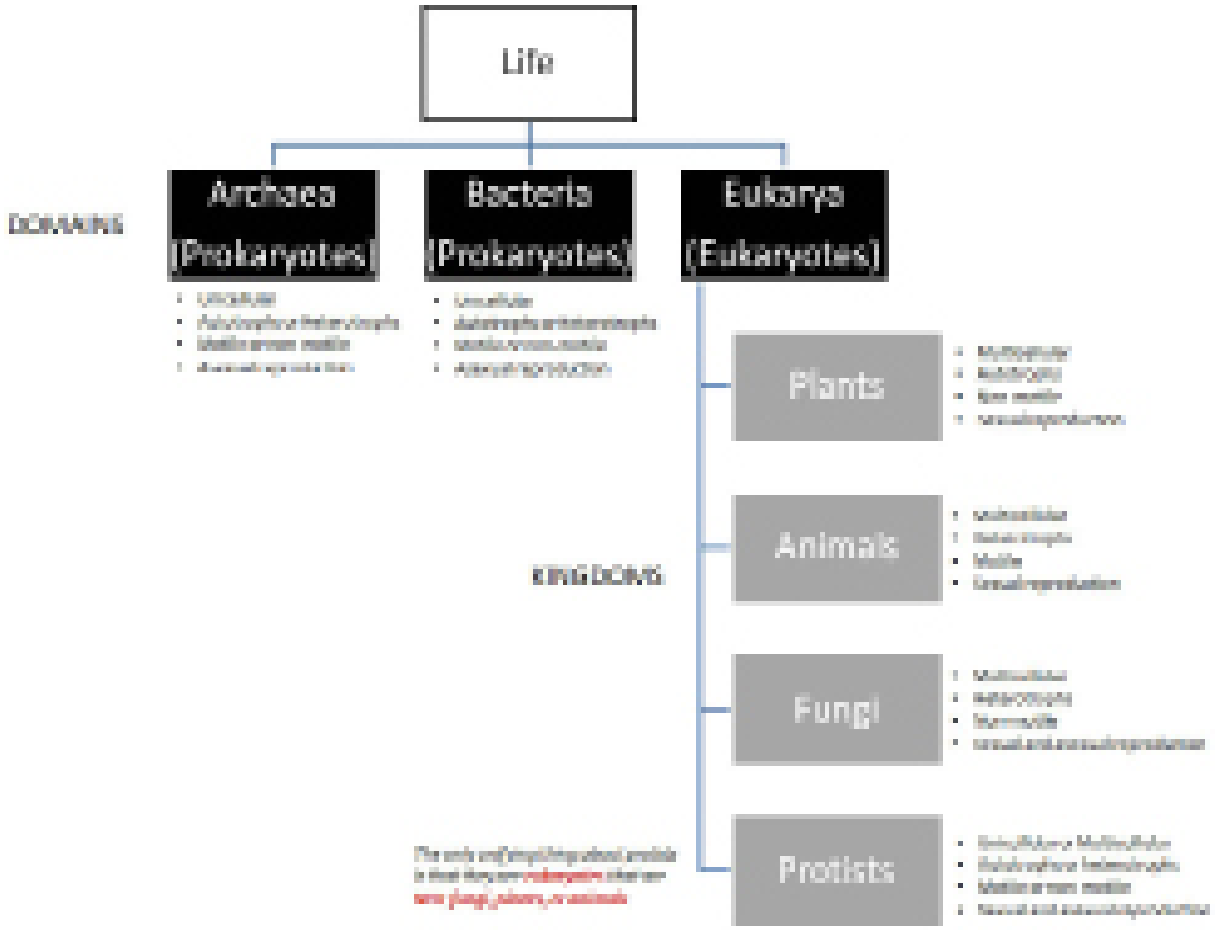

Figure 1. One representation of the heirrchy of life. All living organisms can be classified into one of these categories.

Assignment

The phylogenetic tree below (Figure 2) presents the representative organisms you will be observing during our biodiversity labs and learning about in lecture. This tree will allow you to not only see the different domains and kingdoms, but more importantly, see the history of life's divergence. What are the evolutionary events that have occurred in our living world to result in the biodiversity that we see today?

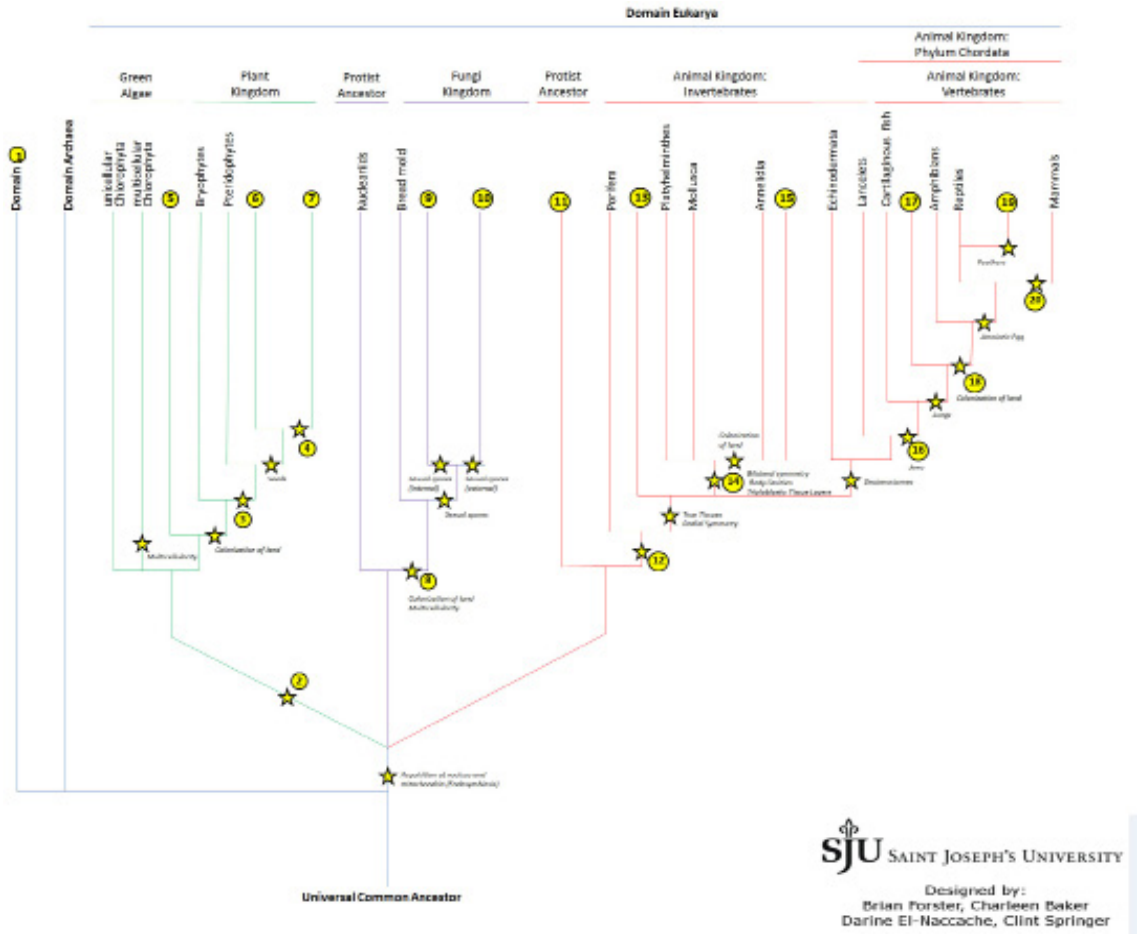

Figure 2. Tree of Life covering organisms and evolutionary events discussed in Biology 165. Numbers indicate 20 missing components of the tree.

Identify the twenty missing components to the tree. The missing components may be a phylum, group, or an evolutionary step leading to the development of a new species. While an evolutionary event is indicated for numbers 8, 14, 16 and 18, you are required to indicate an *additional* event.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

Notes for the Instructor

Assigning this Activity

It is recommended that this tree assignment be given in conjunction or immediately after a course's lecture and laboratory activities on organismal biology. In our course, we have assigned the tree in conjunction with our lab activities. Students are given approximately four weeks to complete the assignment and are not provided with a word bank listing the answers. By working through this tree, the student prepares for themselves a study guide on all the organisms they have seen in Biology 165. It not only allows them to review the content material, but more importantly, it allows students to see the big picture of biodiversity on Earth.

Answers to the Activity: The missing components of Fig. 2 are shown below in Fig. 3.

Adapting this activity to any laboratory or classroom

Modifying the tree

Recognizing that different instructors teaching the topic of biodiversity may choose to have their students examine different organisms and events shown in Figures 2 and 3, the tree can be easily edited. Editable files of the tree for Microsoft PowerPoint, Adobe Photoshop and Adobe Illustrator are available as Supplemental Information. Any questions or problems editing the tree should be directed to the corresponding author.

Modifying the Assignment

The assignment presented here was designed specifically for non-science majors taking our Biology 165 course. Regardless, it can be easily adapted to any laboratory or classroom. It can also be modified and given as an assignment to science majors as well. The authors recommend the following as alternative forms of the assignment:

- Having the students identify more than twenty items of the tree.
- Providing students with a word bank with all the organisms and/or evolutionary events and an empty tree diagram. Students would then have to fill in the complete tree.
- Rather than giving the tree and having the students fill it in, provide the students with the names of the organisms and/or evolutionary events and have them draw the tree.

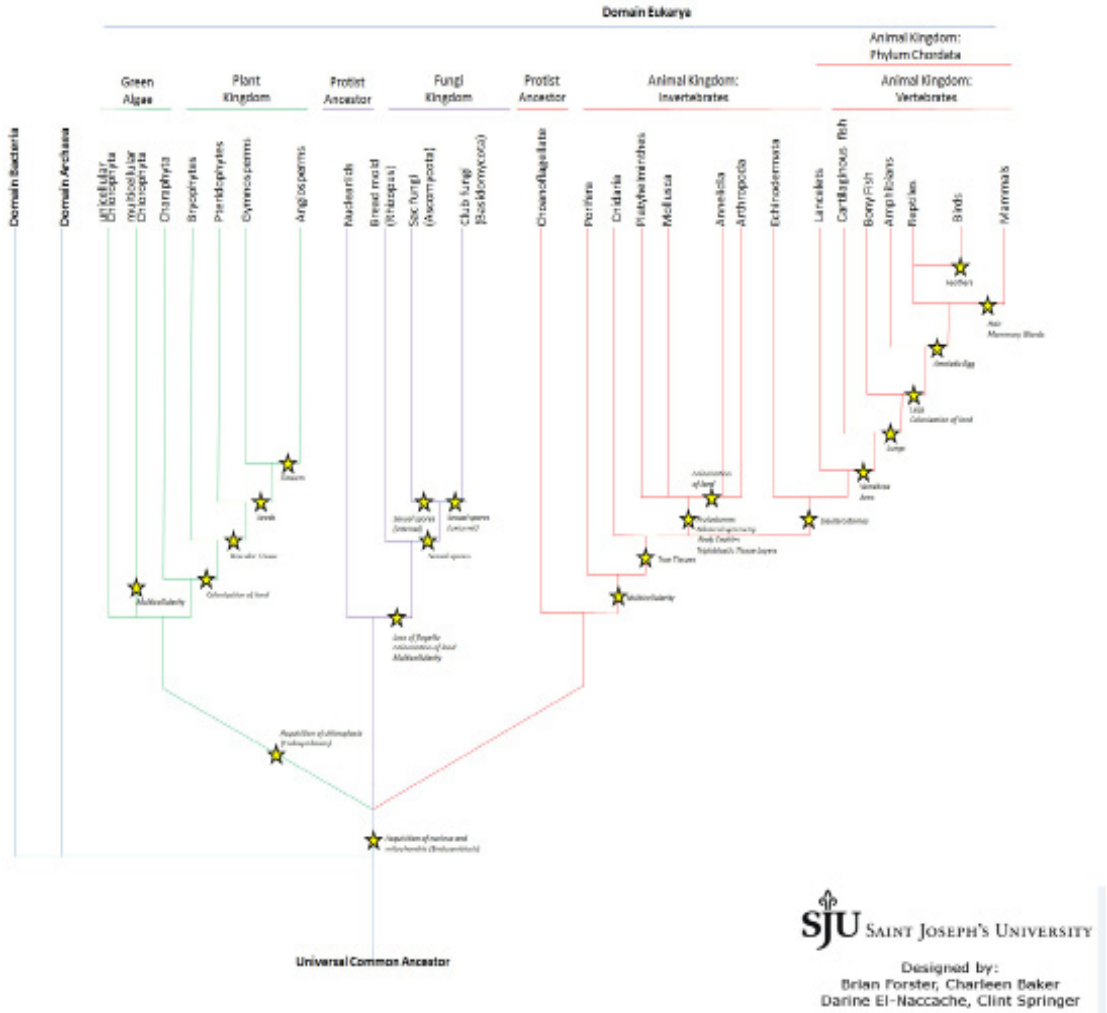

Figure 3. Tree of Life with missing components identified.

Student Reaction to the Assignment

Typically, when students taking Biology 165 are assigned this activity, the students feel overwhelmed and believe the assignment to be too hard to complete. However, as they work through the tree in conjunction with our biodiversity lab exercises, students discover that they are able to complete the assignment. We surveyed our students on the usefulness of this activity. On a scale of 1 through 5 (5 being the most useful), approximately 70% of our students ranked the usefulness of the activity a 4 or 5. Positive feedback from the students included, "nice summary of the course," "helped with the exam," and "this was very helpful!" Negative feedback from the students included, "assignment was hard," and "didn't understand it for a while."

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About the Authors

Brian M. Forster received his Ph.D. from Cornell University. In 2011, he joined the faculty of Saint Joseph's University. Dr. Forster is the laboratory coordinator for the natural science laboratory-based classes designed for students who are not science majors. He teaches courses in general biology, environmental science and a course in microbiology designed for students wishing to enter nursing or allied health programs.

Charleen M. Baker received her Ph.D. from University of Minnesota. Her research interests have been in the field of plant biotechnology. In 2012, she redirected her career to teaching biology labs at Burlington County College, Arcadia University and Saint Joseph's University. Currently Dr. Baker is teaching freshman biology at Richard Stockton College of New Jersey.

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