Title	**Exploring Evolution Using Scientific Databases** **Curriculum Unit Plan**
Introduction	In these lessons plans, students will explore scientific databases to understand evolutionary relationships between organisms. Through a variety of activities, students will create and interpret phylogenetic trees, navigate scientific databases of fossil data, create hypotheses about plant migration over time. Students will create manipulative phylogenetic trees, mine data from the Neotoma website, map the migration of magnolia and hemlock since the Last Glacial Maximum using fossil-pollen data, and infer the relatedness of organisms using fossil-pollen data. Students will also explore the applications of using fossil-pollen data to predict the outcome of global climate change. By utilizing data from scientific databases, experiencing a Socratic seminar discussion, and participating in inquiry-based practices, this curriculum unit will engage students in the use and importance of synthetic research as it applies to evolutionary biology. Students will understand how the significance and utility of synthetic research, and create hypotheses that predict how global climate change will affect the geographic ranges of organisms.
Learning Outcomes	• Students will explain that evolution is change over time. • Students will describe how the environment affects natural selection of organisms. • Students will apply data and to plot arboreal migration over time. • Students will analyze data to build phylogenetic trees based on migration patterns. • Students will evaluate phylogenetic trees to determine evolutionary relationships, and predict effects of environmental change. • Students will create hypotheses to predict evolutionary relationships between organisms. • Students will evaluate primary documents and make inferences.
Curriculum Alignment	**Alignment to NC Essential Standards for Biology** • **Objective 3.4:** Explain the theory of evolution by natural selection as a mechanism for how species change over time. • **Objective 3.5:** Analyze how classification systems are developed based upon speciation. **Alignment to AP Biology Curriculum Framework** • **Enduring understanding 1.A**: Change in the genetic makeup of a population over time is evolution. • **Enduring understanding 1.B**: Organisms are linked by lines of descent from common ancestry. • **Enduring understanding 1.C**: Life continues to evolve within a changing environment.

Classroom Time	• 4, 50-minute class periods or 2-3 block periods for all 4 activities
	  o 1, 50-minute class period for *Darwin's Tree Seminar*
	  o 1, 50-minute class period for *Pipe Cleaner Trees*
	  o 1, 50-minute class periods *Mining the Neotoma Database*
	  o 1, 50-minute class periods for *Have Pollen…Will Travel*

Materials Needed	• Pipe cleaners, 5 different colors, per group of 2-3 students
	• Colored pencils, same as pipe cleaners plus other assorted colors
	• Computers with internet access
	• LCD projector
	• Student Handouts
	  o Darwin's Tree Socratic Seminar
	  o Pipe Cleaner Trees
	  o Mining Data for Synthetic Research
	  o Creating Trees from Trees

Technology Resources	• Computer with internet access • LCD Projector
Pre-Activities	These activities are designed to be part of a unit on evolution and/or classification. Students should be familiar with the historical context of Charles Darwin's development of the theory of evolution by means of natural selection.
Activities	• Darwin's Tree Socractic Seminar • Pipe Cleaner Trees • Mining the Neotoma Database • Have Pollen…Will Travel
Assessment	• Pre-Module online survey on evolution as a formative assessment • Darwin's Tree Seminar graded according to seminar grading rubric • Pipe Cleaner Trees graded according to answer key and through classroom discussion • Mining Data for Synthetic Research lab report graded according to lab report rubric • Creating Trees from Trees graded according to answer key and through lab report which is graded according to rubric
Modifications	• Provide worksheet of data for students if there is not internet or computer access • Teacher can project data on LCD projector and walk through procedure with entire class • Students can use colored pencils to plot data on maps
Alternative Assessments	
Supplemental Information	• Paideia Institute – Seminar Plans and Tools http://paideia.org/for-teachers/materials-to-download/ • Making Cladograms Activity from Evolution and Nature of Science Institutes (ENSI) http://www.indiana.edu/~ensiweb/lessons/mclad.ws.pdf • Neotoma Paleoecological Database http://www.neotomadb.org/about/category/about • Reading a Phylogenetic Tree: The Meaning of Monophyletic Groups http://www.nature.com/scitable/topicpage/reading-a-phylogenetic-tree-the-meaning-of-41956
Critical Vocabulary	Evolution, Migration, Range shift, Phylogeny, Phylogenetic trees, Databases, Node, Branch, Taxon/taxa, Arboreal, Natural selection, Common ancestor
Comments to the Teacher	
Author Information	Robin Bulleri teaches Biology and AP Biology at Carrboro High School. She has taught for over 13 years and holds a B.S. in Science Education and an M.Ed. in Education Policy. Mrs. Bulleri has presented at science conferences, received numerous classroom grants, written curricula for summer and after-school programs, and mentored student-teachers from the UNC Best program. She is a past North Carolina Science Leadership Fellow, science department chair, and NCSCA 2A State Soccer Coach of the Year. As a Kenan Fellow, Mrs. Bulleri externed at the National Evolutionary Synthesis Center, where she conducted teacher workshops and studied migration patterns of North American plants since the last glacial maximum.

Title	**Exploring Evolution Using Scientific Databases** **Pipe Cleaner Trees**
Introduction	In this activity, students will create phylogenetic trees using pipe cleaners. They will manipulate their trees to infer evolutionary relationships between organisms. . This activity can be used to introduce or reinforce phylogenetic tree concepts.
Learning Outcomes	• Students will explain that evolution is change over time. • Students will evaluate phylogenetic trees to infer evolutionary relationships between organisms.
Curriculum Alignment	**Alignment to NC Essential Standards for Biology** • **Objective 3.4:** Explain the theory of evolution by natural selection as a mechanism for how species change over time. • **Objective 3.5:** Analyze how classification systems are developed based upon speciation. **Alignment to AP Biology Curriculum Framework** • **Enduring understanding 1.A**: Change in the genetic makeup of a population over time is evolution. • **Enduring understanding 1.B**: Organisms are linked by lines of descent from common ancestry. • **Enduring understanding 1.C**: Life continues to evolve within a changing environment.
Classroom Time	• 1, 50 minute class period o Pre-activity discussion: 5 to 15 minutes depending on student questions o Student activity: 20 to 30 minutes depending on student ability levels o Post-activity discussion: 3 to 5 minutes for review and putting away materials
Materials Needed	• Pipe cleaners, 5 different colors, per group of 2-3 students • Colored pencils, same as pipe cleaners plus other assorted colors • LCD projector • Student Handouts
Technology Resources	• None required • LCD projector is convenient to show other examples of phylogenetic trees
Pre-Activities	This activity is designed to be part of a unit on evolution and/or classification. Students should be familiar with the historical context of Charles Darwin's development of the theory of evolution by means of natural selection. Students should understand traits by which organisms are classified.
Activities	1. Teacher will open the activity by showing students a few examples of phylogenetic (on the board or using and LCD projector connected to a computer). Teacher should pose the question, "What do these pictures show?" and tailor the discussion to student responses. 2. Teacher explains that phylogenetic trees are used to show evolutionary relationships between organisms. Phylogenetic trees can take many forms, and look very different from each other, yet are interpreted in the same way. 3. Teacher asks, "What traits are used to classify organisms?" Student responses will include, fossils, anatomy, DNA, biochemistry, embryology, etc. 4. Teacher will distribute the materials, and introduce the activity using the students handout. 5. Allow students 15–20 minutes to work independently on their trees while monitoring their progress. 6. If students finish their trees before the last five minutes of class, have them begin the analysis and conclusion questions. 7. When all students have completed their trees, have students compare their trees to other groups. Stress that phylogenetic trees are models for evolutionary relationships. They can be created and

	drawn in several correct ways. Teacher should model the various ways trees can differ by using one of the group's tree, and rotating branches and nodes. It is the interpretation of the tree which is the most significant use of phylogenetic trees. 8. In the last remaining minutes of class, review what they have done and find out if there are any questions. Students who did not finish in class should complete their analysis and conclusion questions for homework. Assure students that only their trees will be assessed for accuracy whereas the rest of their score depends on the thought and quality of their responses. Ensure that all students can complete the assignment.
Assessment	The teacher will score the student responses based upon completion of each step of the activity. The student-created tree should be graded for accuracy and the five conclusion questions based upon use of critical thinking skills. An answer key for the questions is provided in the supplemental information.
Modifications	Teacher can project activity on LCD projector and walk through procedure with entire class
Alternative Assessments	ELL students may have the directions read to them by the teacher or another student. Teacher may choose to demonstrate the activity via modeling.
Supplemental Information	• Making Cladograms Activity from Evolution and Nature of Science Institutes (ENSI) http://www.indiana.edu/~ensiweb/lessons/mclad.ws.pdf • Reading a Phylogenetic Tree: The Meaning of Monophyletic Groups http://www.nature.com/scitable/topicpage/reading-a-phylogenetic-tree-the-meaning-of-41956
Critical Vocabulary	Evolution, Phylogeny, Phylogenetic trees, Node, Branch, Taxon/taxa, Natural selection , Common ancestor, Derived traits, Shared traits, Ancestral traits
Comments to the Teacher	
Author Information	Robin Bulleri teaches Biology and AP Biology at Carrboro High School. She has taught for over 13 years and holds a B.S. in Science Education and an M.Ed. in Education Policy. Mrs. Bulleri has presented at science conferences, received numerous classroom grants, written curricula for summer and after-school programs, and mentored student-teachers from the UNC Best program. She is a past North Carolina Science Leadership Fellow, science department chair, and NCSCA 2A State Soccer Coach of the Year. As a Kenan Fellow, Mrs. Bulleri externed at the National Evolutionary Synthesis Center, where she conducted teacher workshops and studied migration patterns of North American plants since the last glacial maximum.

Name ___________________________________ Date ___________ Period________

Biology
Pipe Cleaner Trees

Introduction

Evolutionary scientists often use cladograms or phylogenetic trees to illustrate relationships between groups of organisms. However, there are several ways to create and interpret these "trees", leading to some confusion. In this activity students will practice creating phylogenetic trees, and manipulate them to demonstrate both their usefulness and flexibility.

Pre-Lab Questions

1. What does a phylogenetic tree illustrate?
2. What are some problems creating phylogenetic trees?
3. What do the nodes represent?
4. What occurs along the branches?
5. What types of evidence are used to create phylogenetic trees?

Materials

- 5 pipe cleaners (1each of pink, blue, orange, green, purple)
- Colored pencils that match the pipe cleaner colors

Procedure

1. Consider the following organisms: human, crocodile, trout, octopus, and chimpanzee.
2. Using the pipe cleaners, create a phylogenetic tree that illustrates the evolutionary relationships between the above organisms.
3. You may only twist and bend the pipe cleaners. You may not cut them, and you must use all of them.
4. Show your teacher your tree, and draw it in the space to the right. Label the nodes, 1 → 4, and label the ends of the branches with the organisms.
5. When you're finished with your tree, carefully disassemble it, and return the materials to your teacher.

Guiding Questions

1. Does your tree look the same as other groups'? How might they differ?

2. Rotate branches D and E around the node. Did you change the interpretation of the tree? Explain.

3. Assign the following organisms to the appropriate branch on your tree: human, crocodile, trout, octopus, and chimpanzee. Record below.
    a. Branch A: ______________________________________
    b. Branch B: ______________________________________
    c. Branch C: ______________________________________
    d. Branch D: ______________________________________
    e. Branch E: ______________________________________

4. Assign an "evolution event" (a new trait), to each node. There are several correct answers. Record below.
    a. Node1: _________________________________
    b. Node2: _________________________________
    c. Node3: _________________________________
    d. Node4: _________________________________

5. Which type of evolution occurs after each node?

6. What node # is the last common ancestor for the human and
    a. Chimpanzee? _______
    b. Octopus? _______

7. Do the lengths of the branches indicate anything about time?

8. Each taxon derives from a common ancestor. Is the common ancestor extinct? Explain.

9. Was the tree you created accurate? Explain.

10. How are phylogenetic trees useful in studying the evolutionary history of organisms?

References

Halverson, Kristy (2010). *The American Biology Teacher*, Vol. 72, No. 4, pages 223-224.

Name ___________________________________ Date ___________ Period________

Biology
Pipe Cleaner Trees

Introduction

Evolutionary scientists often use cladograms or phylogenetic trees to illustrate relationships between groups of organisms. However, there are several ways to create and interpret these "trees", leading to some confusion. In this activity students will practice creating phylogenetic trees, and manipulate them to demonstrate both their usefulness and flexibility.

Pre-Lab Questions

1. What does a phylogenetic tree illustrate?
   Evolutionary history of organisms

2. What are some problems creating phylogenetic trees?
   Phylogenies can be interpreted differently. Trees might look different, but be interpreted the same way.

3. What do the nodes represent?
   Speciation events

4. What occurs along the branches?
   New species evolve

5. What types of evidence are used to create phylogenetic trees?
   Fossil evidence, comparative anatomy, DNA/RNA/protein comparisons

Materials

- 5 pipe cleaners (1each of pink, blue, orange, green, purple)
- Colored pencils that match the pipe cleaner colors

Procedure

6. Consider the following organisms: human, crocodile, trout, octopus, and chimpanzee.
7. Using the pipe cleaners, create a phylogenetic tree that illustrates the evolutionary relationships between the above organisms.
8. You may only twist and bend the pipe cleaners. You may not cut them, and you must use all of them.
9. Show your teacher your tree, and draw it in the space to the right. Label the nodes, 1 → 4, and label the ends of the branches with the organisms.
10. When you're finished with your tree, carefully disassemble it, and return the materials to your teacher.

Guiding Questions

1. Does your tree look the same as other groups'? How might they differ?
   Trees might look different in the how the branches are oriented to each other (left/right are switched)

2. Rotate branches D and E around the node. Did you change the interpretation of the tree? Explain.
   No – D and E still share the same most recent common ancestor

3. Assign the following organisms to the appropriate branch on your tree: human, crocodile, trout, octopus, and chimpanzee. Record below.
   a. Branch A: _ octopus___________________________________
   b. Branch B: _ trout ___________________________________
   c. Branch C: __crocodile ____________________________
   d. Branch D: __chimpanzee/human___________________________________
   e. Branch E: __human/chimpanzee___________________________________

4. Assign an "evolution event" (a new trait), to each node. There are several correct answers. Record below.
   a. Node1: _vertebrae________________________________
   b. Node2: _lungs_ (many answer will work)_____________________________
   c. Node3: _placenta (many answers will work)________________________________
   d. Node4: _many answer will work________________________________

5. Which type of evolution occurs after each node?
   Divergent

6. What node # is the last common ancestor for the human and
   a. Chimpanzee? _4______
   b. Octopus? __1_____

7. Do the lengths of the branches indicate anything about time?
   Not usually

8. Each taxon derives from a common ancestor. Is the common ancestor extinct? Explain.
   The common ancestor might still be extant. This tree infers the common ancestor is extinct

9. Was the tree you created accurate? Explain.
   yes

10. How are phylogenetic trees useful in studying the evolutionary history of organisms?
    Trees are useful in illustrating how related organisms are to each other.

References

Halverson, Kristy (2010). *The American Biology Teacher*, Vol. 72, No. 4, pages 223-224.

Title	Exploring Evolution Using Scientific Databases Darwin's Tree Socractic Seminar
Introduction	In this activity the teacher will facilitate a Socratic seminar using the Paideia method about the tree image from Charles Darwin's from Notebook B: Transmutation, page 36 (1837-1838).
Learning Outcomes	• Students will explain that evolution is change over time. • Students will evaluate phylogenetic trees to determine evolutionary relationships. • Students will evaluate primary documents and make inferences.
Curriculum Alignment	**Alignment to NC Essential Standards for Biology** • **Objective 3.4:** Explain the theory of evolution by natural selection as a mechanism for how species change over time. • **Objective 3.5:** Analyze how classification systems are developed based upon speciation. **Alignment to AP Biology Curriculum Framework** • **Enduring understanding 1.A**: Change in the genetic makeup of a population over time is evolution. • **Enduring understanding 1.B**: Organisms are linked by lines of descent from common ancestry. • **Enduring understanding 1.C**: Life continues to evolve within a changing environment.
Classroom Time	1, 50-minute class period, plus 10-15 minutes during the previous class to prepare for the seminar
Materials Needed	Copy of Notebook B: Transmutation, page 36, by Charles Darwin (1837-1838)
Technology Resources	No technology resources are necessary
Pre-Activities	These activities are designed to be part of a unit on evolution and/or classification. Students should be familiar with the historical context of Charles Darwin's development of the theory of evolution by means of natural selection. Before the seminar, the teacher should provide some historical context for Darwin's notebooks.
Activities	Darwin's Tree Socratic Seminar 1. Teacher will prepare a seminar plan with opening, content, and conclusion questions according to the Paideia seminar lesson plan. 2. Students will reflect on the Darwin's tree image for a few minutes, making necessary notes or talking points on their paper. 3. In a round-robin or hopping-robin format, students will share their impression of the image. 4. Teacher will facilitate a discussion among the students, using the content questions to keep the discussion going. 5. Teacher will conclude the seminar with conclusion question and activity. Students will reflect and assess themselves based on their personal seminar goals.
Assessment	Teacher will assess students based on a seminar participation rubric. Students will assess themselves based on their personal seminar goals they developed before the seminar activity. Teacher will make several informal notes about student understanding of concepts and ideas discussed in the seminar.
Modifications	
Alternative Assessments	If a student is absent, he/she can write a reflective essay based on the Darwin's tree image.

Supplemental Information	• Darwin Online. http://darwin-online.org.uk/ • Paideia Institute – Seminar Plans and Tools http://paideia.org/for-teachers/materials-to-download/
Critical Vocabulary	Evolution, Phylogeny, Phylogenetic trees, Natural selection, Common ancestor
Comments to the Teacher	Using a seminar-based lesson can be intimidating for teachers who are not accustomed this type of activity. It is important to discuss with students the expectations of behavior and participation prior to the seminar. Equally important is reflection of the lesson afterwards. The seminar format can be a powerful tool to encourage student dialogue. Seminars are especially useful in ELL classes, and classes where students struggle to write or read.
Author Information	Robin Bulleri teaches Biology and AP Biology at Carrboro High School. She has taught for over 13 years and holds a B.S. in Science Education and an M.Ed. in Education Policy. Mrs. Bulleri has presented at science conferences, received numerous classroom grants, written curricula for summer and after-school programs, and mentored student-teachers from the UNC Best program. She is a past North Carolina Science Leadership Fellow, science department chair, and NCSCA 2A State Soccer Coach of the Year. As a Kenan Fellow, Mrs. Bulleri externed at the National Evolutionary Synthesis Center, where she conducted teacher workshops and studied migration patterns of North American plants since the last glacial maximum.

Title	**Exploring Evolution Using Scientific Databases** **Mining the Neotoma Database**
Introduction	In this activity students use internet resources to complete a mini-webquest of the Neotoma Paleoecological Database. The purpose of the webquest is for students to explore the types of data stored on Neotoma and how the data is used.
Learning Outcomes	• Students will explain that evolution is change over time. • Students will evaluate phylogenetic trees to determine evolutionary relationships, and predict effects of environmental change. • Students will create hypotheses to predict evolutionary relationships between organisms. • Students will evaluate primary documents and make inferences.
Curriculum Alignment	**Alignment to NC Essential Standards for Biology** • **Objective 3.4:** Explain the theory of evolution by natural selection as a mechanism for how species change over time. • **Objective 3.5:** Analyze how classification systems are developed based upon speciation. **Alignment to AP Biology Curriculum Framework** • **Enduring understanding 1.A**: Change in the genetic makeup of a population over time is evolution. • **Enduring understanding 1.B**: Organisms are linked by lines of descent from common ancestry. • **Enduring understanding 1.C**: Life continues to evolve within a changing environment.

Classroom Time	• 1, 50-minute class period; advanced classes can complete this activity for homework
	  o 5-10 minutes to introduce activity and get out laptops
	  o 30-40 minutes to complete activity
	  o 5 minutes to wrap up and put away laptops

Materials Needed	• Computers with internet access • LCD projector • Student Handouts
Technology Resources	• Computer with internet access • LCD Projector
Pre-Activities	These activities are designed to be part of a unit on evolution and/or classification. Students should be familiar with the historical context of Charles Darwin's development of the theory of evolution by means of natural selection. The idea of scientific databases should be explained to students prior to the activity.
Activities	1. To open the activity, the teacher should review the concepts from the prior days or perhaps review the idea of synthetic research. The time the teacher wishes to dedicate to this activity will vary depending on the nature of the class. 2. The teacher will explain that *Neotoma* is a database of ecological data from the last 20,000-100,000 years, including fossil-pollen data. 3. Allow students 20-30 minutes to work independently answering the questions on their lab sheets while monitoring their progress. 4. In the remaining minutes of class, review what students have done and find out if there are any questions. Students who did not finish in class should complete their data and/or analysis and conclusion questions for homework. Ensure that all students can complete the assignment.

Assessment	The student-created responses should be graded for accuracy and conclusion question based upon use of critical thinking skills. An answer key for the questions is provided in the supplemental information.
Modifications	This activity can be completed in class. Advanced classes might complete this activity for homework.
Alternative Assessments	
Supplemental Information	• Making Cladograms Activity from Evolution and Nature of Science Institutes (ENSI) http://www.indiana.edu/~ensiweb/lessons/mclad.ws.pdf • Neotoma Paleoecological Database http://www.neotomadb.org/about/category/about • Reading a Phylogenetic Tree: The Meaning of Monophyletic Groups http://www.nature.com/scitable/topicpage/reading-a-phylogenetic-tree-the-meaning-of-41956
Critical Vocabulary	Evolution, Migration, Range shift, Phylogeny, Phylogenetic trees, Databases, Arboreal, Natural selection, Common ancestor, Last Glacial Maximum, Palynology, Taphonomy, Geochronology
Comments to the Teacher	
Author Information	Robin Bulleri teaches Biology and AP Biology at Carrboro High School. She has taught for over 13 years and holds a B.S. in Science Education and an M.Ed. in Education Policy. Mrs. Bulleri has presented at science conferences, received numerous classroom grants, written curricula for summer and after-school programs, and mentored student-teachers from the UNC Best program. She is a past North Carolina Science Leadership Fellow, science department chair, and NCSCA 2A State Soccer Coach of the Year. As a Kenan Fellow, Mrs. Bulleri externed at the National Evolutionary Synthesis Center, where she conducted teacher workshops and studied migration patterns of North American plants since the last glacial maximum.

Name ________________________________ Date ___________ Period________

AP Biology

Mining the Neotoma Database

Introduction

In the past few years, scientists have come to realize the benefits of collaboration and sharing of data. Additionally, improvements in computers and data storage now allow scientists to integrate their data into public databases, so that others may use it. Synthetic research, or research using previously collected data, allows scientists to ask novel questions and use old data in new ways, and to collaborate with each other to explore a wider range of research topics. Neotoma is an example of a database created by the integration of previously separate databases. In this activity, you will acquaint yourself with the information stored in Neotoma, and ways that scientists can use these data.

Navigating Neotoma

Go to the website http://www.neotomadb.org/

1. Click on the "About" link and go to "Science". What is Neotoma?
   ____
   ____
   ____

2. What is the significance of the name "Neotoma"? Google it if you can't find it on the site.
   ____
   ____
   ____

3. From where does Neotoma get its data?
   ____
   ____
   ____

Click on "Workgroups" then click on "pollen".

4. Why are pollen fossils ideal specimens to work with?
   ____
   ____
   ____

5. What can we learn from fossil-pollen data?
   ____
   ____
   ____

Continue to explore the Neotoma website to answer the following questions.

6. Who is responsible for the maintenance of Neotoma?
   ____
   ____
   ____

7. What are the benefits of conducting synthetic research (using data from databases) for research?
____
____
____

8. Describe how the use of synthetic research through databases encourages scientists from across disciplines to collaborate?
____
____
____

9. Much of Neotoma's data comes from the Pliocene-Quaternary section of the Geologic Time Scale. Why is that such a useful age for studying fossils?
____
____
____

10. Search for the following terms on the Neotoma website and define them below:
    a. Taphonomy____
    ____
    b. Geochronology____
    ____
    c. Palynology____
    ____

Conclusions

Many of the fossil-pollen data in Neotoma provide an extraordinary window on what terrestrial communities were like during and after the Last Glacial Maximum. Research this geologic event. Explain the significance of the ice sheet and its decline to both plant and animal life in North America. Describe how plant and animal life have changed since that time.

____
____
____
____
____
____
____
____
____
____
____
____
____

Acknowledgements

Information and data were obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org/), and the work of the data contributors and the Neotoma community is gratefully acknowledged. This activity was created as part of the Kenan Fellows Program. Special thanks to Dr. Paul Harnik, NESCent scientist, who introduced me to Neotoma as part of our research project.

Name __Answer Key______________________ Date ___________ Period________

AP Biology
Mining the Neotoma Database

Introduction
In the past few years, scientists have come to realize the benefits of collaboration and sharing of data. Additionally, improvements in computers and data storage now allow scientists to integrate their data into public databases, so that others may use it. Synthetic research, or research using previously collected data, allows scientists to ask novel questions and use old data in new ways, and to collaborate with each other to explore a wider range of research topics. Neotoma is an example of a database created by the integration of previously separate databases. In this activity, you will acquaint yourself with the information stored in Neotoma, and ways that scientists can use these data.

Navigating Neotoma
Go to the website http://www.neotomadb.org/

1. Click on the "About" link and go to "Science". What is Neotoma?
   Neotoma is an international, collaborative database of pollen-fossil data from the Pliocene-Quaternary periods.

2. What is the significance of the name "Neotoma"? Google it if you can't find it on the site.
   Neotoma is part of the scientific name for the "packrat".

3. From where does Neotoma get its data?
   Neotoma is a conglomeration of several databases. Scientists donate their data to be used by other scientists in the future.

Click on "Workgroups" then click on "pollen".

4. Why are pollen fossils ideal specimens to work with?
   Fossil-pollen is ubiquitous in the fossil record. It is well preserved, and fairly easy to examine.

5. What can we learn from fossil-pollen data?
   Fossil-pollen data tells us about the distribution and migration of plants since the Last Glacial Maximum. One can then infer about the climate, evolution, and biodiversity of plants since the LGM.

Continue to explore the Neotoma website to answer the following questions.

6. Who is responsible for the maintenance of Neotoma?
   Neotoma is primarily maintained by Penn State. Researchers are responsible to provide accurate, reliable data.

7. What are the benefits of using synthetic research (using data from databases) for research?
   Synthetic data allows researchers to use previous data in novel ways, by combining data, or adding new data to answer questions. Synthetic data avoids costly field research and encourages collaboration between scientists.

8. Describe how the use of synthetic research through databases encourages scientists from across disciplines to collaborate?
   Scientists of different fields might collect similar data, but to answer different questions. Synthetic data encourages scientists to collaborate on projects together, using their data together.

9. Much of Neotoma's data comes from the Pliocene-Quaternary section of the Geologic Time Scale. Why is that such a useful age for studying fossils?

Many fossils were created or preserved in the ice sheet. Since the LGM, there has been rapid migration and speciation of organisms.

10. Search for the following terms on the Neotoma website and define them below:
    a. Taphonomy: study of how organisms become fossilized
    b. Geochronology: the study of dating fossils and rocks
    c. Palynology: the study of pollen and other spores.

Conclusions

Many of the fossil-pollen data in Neotoma provide an extraordinary window on what terrestrial communities were like during and after the Last Glacial Maximum. Research this geologic event. Explain the significance of the ice sheet and its decline to both plant and animal life in North America. Describe how plant and animal life have changed since that time.

_answers will vary ____

____

____

____

____

____

____

____

____

____

____

____

____

Acknowledgements

Information and data were obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org/), and the work of the data contributors and the Neotoma community is gratefully acknowledged. This activity was created as part of the Kenan Fellows Program. Special thanks to Dr. Paul Harnik, NESCent scientist, who introduced me to Neotoma as part of our research project.

Title	**Exploring Evolution Using Scientific Databases** **Have Pollen…Will Travel**
Introduction	In this activity, students will use internet resources to access the Neotoma Paleoecological Database to gather and analyze data concerning range shifts of organisms since the Last Glacial Maximum. Students will use fossil-pollen data in Neotoma to map the migration of the taxon Magnolia since the LGP. Students will use this information to hypothesize about the migration of Hemlock (*Tsuga*). Additionally, students will create a phylogenetic tree of *Tsuga* using their migration data. Lastly, students will draw conclusions about the relatedness of organisms bases on their migration patterns.
Learning Outcomes	• Students will explain that evolution is change over time. • Students will describe how the environment affects natural selection of organisms. • Students will apply data and to plot arboreal migration over time. • Students will analyze data to build phylogenetic trees based on migration patterns. • Students will evaluate phylogenetic trees to determine evolutionary relationships, and predict effects of environmental change. • Students will create hypotheses to predict evolutionary relationships between organisms. • Students will evaluate primary data and make inferences.
Curriculum Alignment	**Alignment to NC Essential Standards for Biology** • **Objective 3.4:** Explain the theory of evolution by natural selection as a mechanism for how species change over time. • **Objective 3.5:** Analyze how classification systems are developed based upon speciation. **Alignment to AP Biology Curriculum Framework** • **Enduring understanding 1.A**: Change in the genetic makeup of a population over time is evolution. • **Enduring understanding 1.B**: Organisms are linked by lines of descent from common ancestry. • **Enduring understanding 1.C**: Life continues to evolve within a changing environment.

Classroom Time	• 1, 50-minute class periods for *Have Pollen…Will Travel.* This activity may be completed at home.
	  o 5 minutes for introduction
	  o 30-40 minutes for student work
	  o 5-10 minutes to discuss conclusions and answer student questions

Materials Needed	• Computers with internet access • LCD projector • Student Handouts
Technology Resources	• Computer with internet access • LCD Projector
Pre-Activities	These activities are designed to be part of a unit on evolution and/or classification. Students should be familiar with the historical context of Charles Darwin's development of the theory of evolution by means of natural selection.
Activities	1. To open the activity, the teacher should review the concepts from the prior days or perhaps review evolution concepts and speciation since the Last Glacial Maximum. The time the teacher wishes to dedicate to this activity will vary depending on the nature of the class. 2. The teacher will explain that Neotoma is a paleoecological database which stores abundant data of North American plants and animals. Most data is derived from fossil collections. This activity uses fossil-pollen data since the Last Glacial Maximum, approximately 20,000 years

	ago. 3. Teacher should describe the significance of the Last Glacial Maximum (LGM). Since the LGM, those organisms which survived the Ice Age have since diverged and migrated significantly. 4. Teacher will model the use of the Neotoma TaxaExplorer web application using an LCD projector hooked up to the computer. The teacher will ensure that all students can access the webpage and can manipulate the data searches. 5. Allow students 30-40minutes to work independently answering the questions on their lab sheets while monitoring their progress. You may wish to give them an additional day in class to complete this activity on a normal schedule or the entire period on a block schedule. 6. If students finish their data collection, have them begin the analysis and conclusion questions. 7. In the remaining minutes of class, review what students have done and find out if there are any questions. Students who did not finish in class should complete their data and/or analysis and conclusion questions for homework (or the next day in class.) Assure students that only their data questions will be assessed upon accuracy whereas the rest of their score depends on the thought and quality of their responses. Ensure that all students can complete the assignment.
Assessment	The student-created responses and data should be graded for accuracy and conclusion questions based upon use of critical thinking skills. An answer key for the questions is provided in the supplemental information. Students should include a copy of their map.
Modifications	• Provide worksheet of data for students if there is not internet or computer access • Teacher can project data on LCD projector and walk through procedure with entire class • Students can use colored pencils to plot data on maps
Alternative Assessments	
Supplemental Information	• Making Cladograms Activity from Evolution and Nature of Science Institutes (ENSI) http://www.indiana.edu/~ensiweb/lessons/mclad.ws.pdf • Neotoma Paleoecological Database http://www.neotomadb.org/about/category/about • Reading a Phylogenetic Tree: The Meaning of Monophyletic Groups http://www.nature.com/scitable/topicpage/reading-a-phylogenetic-tree-the-meaning-of-41956
Critical Vocabulary	Evolution, Migration, Range shift, Phylogeny, Phylogenetic trees, Databases, Arboreal, Natural selection, Common ancestor, Last Glacial Maximum, Palynology, Taphonomy, Geochronology
Comments to the Teacher	Make sure students do not use commas when entering ages into the search box.
Author Information	Robin Bulleri teaches Biology and AP Biology at Carrboro High School. She has taught for over 13 years and holds a B.S. in Science Education and an M.Ed. in Education Policy. Mrs. Bulleri has presented at science conferences, received numerous classroom grants, written curricula for summer and after-school programs, and mentored student-teachers from the UNC Best program. She is a past North Carolina Science Leadership Fellow, science department chair, and NCSCA 2A State Soccer Coach of the Year. As a Kenan Fellow, Mrs. Bulleri externed at the National Evolutionary Synthesis Center, where she conducted teacher workshops and studied migration patterns of North American plants since the last glacial maximum.

Name ______________________________________ Date _________ Period ________

AP Biology
Have Pollen…Will Travel

Part I. Plotting Magnolia Migration

There are roughly 210 species of Magnolia in the world. It is an ancient family, with fossils dating back to 95 million years old. Most species of Magnolia are distributed in Asia or Central America. Eight species of Magnoliaceae are native to the US, including *Magnolia grandiflora* and *Magnolia Virginiana*. Using fossil-pollen data base from *Neotoma*, you will plot the migration of Magnolia since the Last Glacial Maximum.

Pre-Lab Questions

1. What do you know about Magnolias?

 ____
 ____
 ____

2. What was the Last Glacial Maximum? When did it occur?

 ____
 ____
 ____

3. Why are we using fossil-pollen data to track the distribution (or spread) of Magnolia?

 ____
 ____
 ____

4. Make a hypothesis on Magnolia's geographic range shift between 18,000 years ago and today.

 ____
 ____
 ____

Procedure

Go to http://www.neotomadb.org/tools and click on link for TaxaMapper. This application allows the user to visualize occurrences of different fossil types at specified time intervals. You can move and zoom in on the map, and you can click and move the search box.

1. Take a look at the North American map. Note the different mountain ranges and bodies of water. How can geographic features affect the distribution of plant species?

 ____
 ____
 ____

2. Using the TaxaMapper application, you will map the migration of Magnolia since the last glacial maximum. Click on the binoculars icon at the top of the screen.

3. In the search box, enter your search parameters. Do not enter anything for Age Scale or Period. Enter the age range 18,000-15,000, and the Taxon Magnolia. Click “add”. See Figure 1 below.

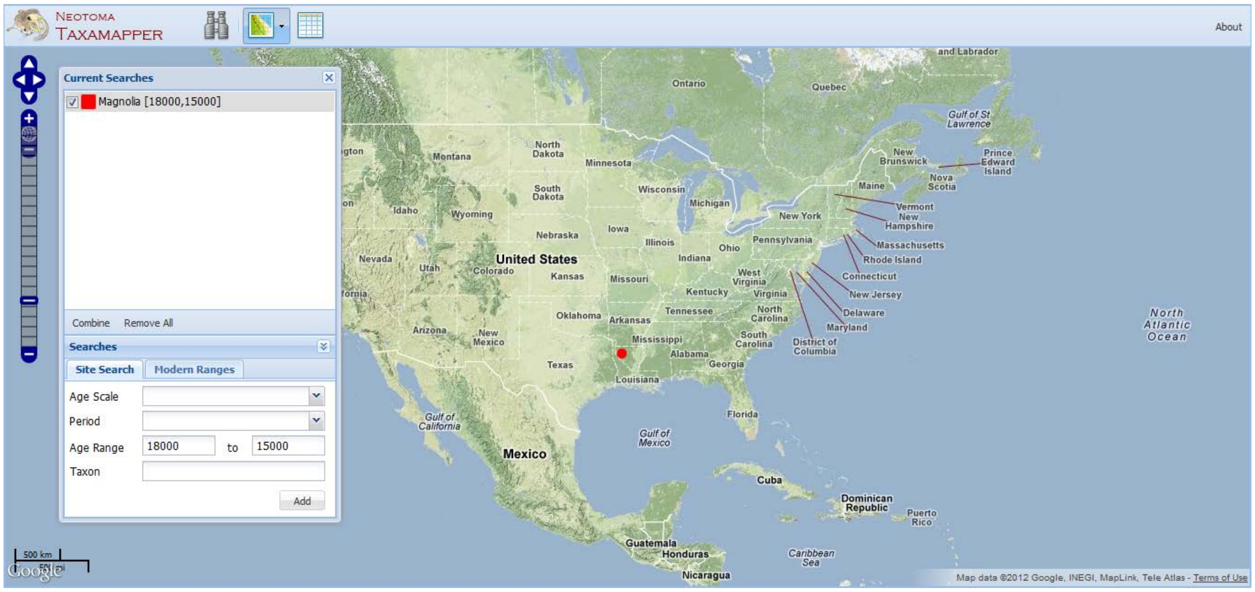

Figure 1. *Screen shot of TaxaMapper search (http://apps.neotomadb.org/taxamapper/)*

4. Now repeat, using time intervals of 3,000 years (i.e. 15,000-12,000), until 0. You can select the colors of the dots by clicking on the colored square in the search box and clicking on a new color. See data table 1 for age ranges.

5. Click on the data table icon at the top of the screen to view the data in a table. Each age range is a tab. Click through the tabs, and examine the site descriptions. What do you notice about the site descriptions?

____

____

____

6. For each age range, describe the migration (if any) of the Magnolia. You can click and unclick the boxes in the search box to view just one age range at a time. Note your observations in data table 1.

7. Save a screen shot of your completed map. You will turn it in with the rest of the lab.

8. Why is it worthwhile to study past geographic range shifts of trees as a result of climate change?

____

____

____

9. Do you data agree with your hypothesis? Why or why not?

____

____

____

Data Table 1

Age Range	Observations
18,000-15,000 BP	
15,000-12,000 BP	
12,000-9,000 BP	
9,000-6,000 BP	
6,000-3,000 BP	
3,000-0 BP	

Part II. Inferring Phylogeny of *Tsuga* Based on Migration

10. Using the same protocol in part I, map the current locations of the following species of Tsuga (hemlock), using the age range 3,000-0 years. Note their relative locations and number of sites in data table 2 below. Save a screenshot of your searches to submit with this lab.

Data Table 2

Tsuga Species	Observations
T. Canadensis	
T. heterophylla	
T. mertensiana	
Pseudotsuga menziesii	

11. Explore Tsuga's geographic range further back in time. Using TaxaMapper, search for Tsuga at the following age ranges. Record your observations in data table 3.

Data Table 3

Age Range	Observations
30,000-20,000	
40,000-30,000	
50,000-40,000	
100,000 - 50,000	

12. Based on your observations in data table 2, create a phylogenetic tree illustrating Tsuga's divergence from a common ancestor. Draw your tree in the space below.

Part III. Drawing Conclusions - *Answer in complete sentences on a separate sheet of paper.*

13. Is the phylogenetic tree you drew at #12 reliable? What other types of evidence should you include to validate your tree?

14. What factors affect tree growth?

15. Why is fossil-pollen data from 500 BP to present day considered unreliable?

16. What patterns do you notice about closely related species and their migration patterns?

17. What can we infer about the traits of those tree species?

18. What can we infer about the phylogeny of the trees based on their patterns of migration?

19. There are two main theories regarding the migration of plants. 1. Plants that are closely related will migrate in a similar pattern because they share similar traits that are well-adapted for the environment, and 2. Plants that are closely related will migrate in a different pattern because they share similar traits that will compete with each other, causing one to either go extinct or adapt new traits. Using your data and your phylogenetic tree, choose which theory is best supported in this activity. Explain, in detail, the reasons for your choice.

20. What factors about the trees and pollen are ignored in this activity, but may lead to future research questions? Write a one page proposal describing a possible research question to explore in the future. Describe a possible hypothesis, how you would go about collecting data, and how you would illustrate your data.

Acknowledgements

Data were obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org/), and the work of the data contributors and the Neotoma community is gratefully acknowledged. This activity was created as part of the Kenan Fellows Program. Special thanks to Dr. Paul Harnik, NESCent scientist, who introduced me to Neotoma as part of our research project.

Name ____Answer Key___________________________ Date _________ Period ________

AP Biology

Have Pollen…Will Travel

Part I. Plotting Magnolia Migration

There are roughly 210 species of Magnolia in the world. It is an ancient family, with fossils dating back to 95 million years old. Most species of Magnolia are distributed in Asia or Central America. Eight species of Magnoliaceae are native to the US, including *Magnolia grandiflora* and *Magnolia Virginiana*. Using fossil-pollen data base from *Neotoma*, you will plot the migration of Magnolia since the Last Glacial Maximum.

Pre-Lab Questions

1. What do you know about Magnolias?
   Answers will vary but might include: magnolia are found throughout the South, they have large , dark-green leaves, they have large, white flowers

2. What was the Last Glacial Maximum? When did it occur?
   20,000 years ago; it was a mile-thick ice sheet extending from Northern Canada into the US as far south as Pennsylvania

3. Why are we using fossil-pollen data to track the distribution (or spread) of Magnolia?
   Fossil-pollen is well-preserved evidence of ancient plant life, fossil-pollen can be used to determine where ancient plants lived

4. Make a hypothesis on Magnolia's geographic range shift between 18,000 years ago and today.
   Answers will vary, but should be in "if…then" format

Procedure

Go to http://www.neotomadb.org/tools and click on link for TaxaMapper. This application allows the user to visualize occurrences of different fossil types at specified time intervals. You can move and zoom in on the map, and you can click and move the search box.

1. Take a look at the North American map. Note the different mountain ranges and bodies of water. How can geographic features affect the distribution of plant species?
   Plants require water, pollen is carried by wind and water so the distribution of pollen could be prevented by mountains and large bodies of water.

2. Using the TaxaMapper application, you will map the migration of Magnolia since the last glacial maximum. Click on the binoculars icon at the top of the screen.

3. In the search box, enter your search parameters. Do not enter anything for Age Scale or Period. Enter the age range 18,000-15,000, and the Taxon Magnolia. Click "add". See Figure 1 below.

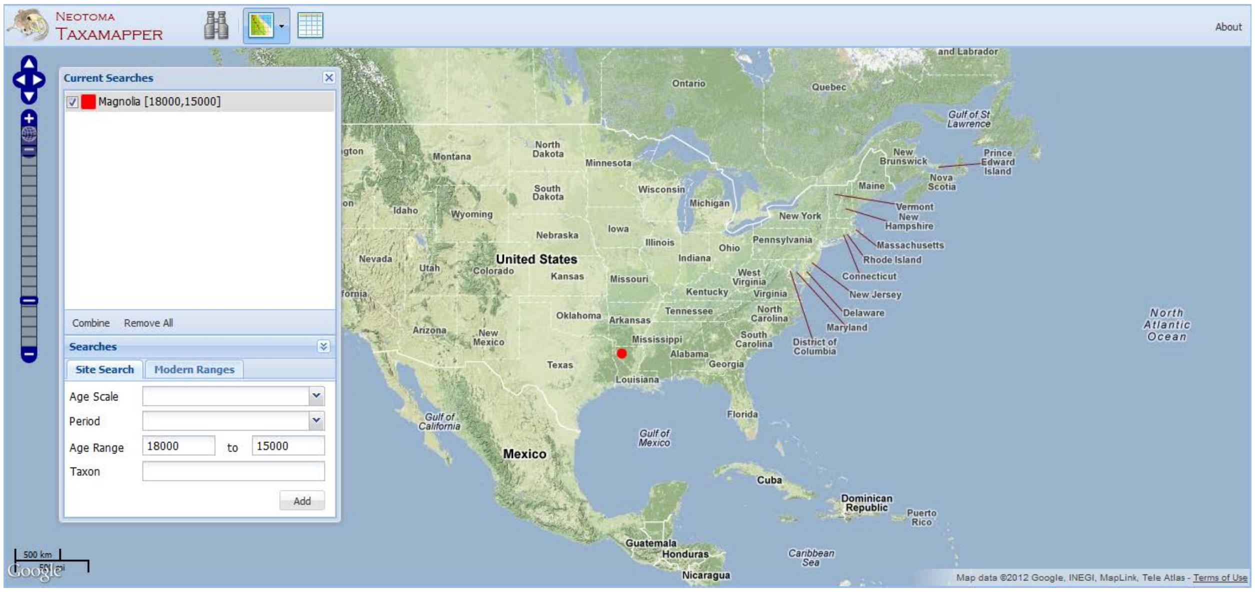

Figure 1. *Screen shot of TaxaMapper search (http://apps.neotomadb.org/taxamapper/)*

4. Now repeat, using time intervals of 3,000 years (i.e. 15,000-12,000), until 0. You can select the colors of the dots by clicking on the colored square in the search box and clicking on a new color. See data table 1 for age ranges.

5. Click on the data table icon at the top of the screen to view the data in a table. Each age range is a tab. Click through the tabs, and examine the site descriptions. What do you notice about the site descriptions?
Most of the sites are near, or describe, bodies of water, such as swamps, bogs, lakes, and springs

6. For each age range, describe the migration (if any) of the Magnolia. You can click and unclick the boxes in the search box to view just one age range at a time. Note your observations in data table 1.

7. Save a screen shot of your completed map. You will turn it in with the rest of the lab.

8. Why is it worthwhile to study past geographic range shifts of trees as a result of climate change?
Answers may vary - We can learn about plant responses to past climate change. We can study how plants have evolved throughout climate change events. We can examine how environmental change affects the distribution of plants

9. Do you data agree with your hypothesis? Why or why not?
Answers will vary. Students need to explain their answer.

Data Table 1 – Students may describe states or regions of the US and Canada. It is up to the teacher to determine how specific student descriptions need to be.

Age Range	Observations
18,000-15,000 BP	One population in NW La; near SW Ark.
15,000-12,000 BP	Four populations from Tenn to Ga and NW Fla Two populations on coast; NE corner of NC and SC coast
12,000-9,000 BP	Two more populations near coast: border of SC, NE Fla, and NC Two population inland: TN and AL
9,000-6,000 BP	Population in FL moved north Other population stable
6,000-3,000 BP	New population in WV, AL Repopulation in N La./Ark
3,000-0 BP	New populations widespread: S Fla, KY, TN, VA coast, PA, and north into Canada

Part II. Inferring Phylogeny of *Tsuga* Based on Migration

10. Using the same protocol in part I, map the current locations of the following species of Tsuga (hemlock), using the age range 3,000-0 years. Note their relative locations and number of sites in data table 2 below. Save a screenshot of your searches to submit with this lab.

Data Table 2

Tsuga Species	Observations
T. Canadensis	1 population in Penn, Me, MN, and many in S Canada
T. heterophylla	Many populations in Pacific NW, BC, 1 pop. In WY
T. mertensiana	Msny populations in Pacific NW, WY, N Ca, scattered in BC and AK
Pseudotsuga menziesii	Only 3 population in Pacific NW

11. Explore Tsuga's geographic range further back in time. Using TaxaMapper, search for Tsuga at the following age ranges. Record your observations in data table 3.

Data Table 3

Age Range	Observations
30,000-20,000	FL, SC, VA, WV, Ind, OH, Mich.
40,000-30,000	Ga, NC/VA coast
50,000-40,000	S Fla
100,000 - 50,000	none

12. Based on your observations in data table 2, create a phylogenetic tree illustrating Tsuga's divergence from a common ancestor. Draw your tree in the space below.

    Answers may vary, but correct tree should show *T. Canadensis* branching off from the other 3 species.

Part III. Drawing Conclusions - *Answer in complete sentences on a separate sheet of paper.*

13. Is the phylogenetic tree you drew at #12 reliable? What other types of evidence should you include to validate your tree?
    No, this is not a reliable tree. One should also consider DNA evidences, more species of Tsuga, more accurate dating of the fossil-pollen data

14. What factors affect tree growth?
    Water availability, climate, wind patterns, soil quality, temperature, sunlight, soil nutrients, predators

15. Why is fossil-pollen data from 500 BP to present day considered unreliable?
    In the last 500 years, the US and Canada have experienced mass migrations of people and plants from all over the world, especially Europe. These migrations introduced thousands of non-native plants. Additionally, farming and deforestation has occurred at a high rate in that time.

16. What patterns do you notice about closely related species and their migration patterns?
    Closely related species tend to follow similar migration patterns.

17. What can we infer about the traits of those tree species?
    Closely related species share traits that are suitable for similar environments.

18. What can we infer about the phylogeny of the trees based on their patterns of migration?
    We can infer that those species which follow similar migration patterns share similar traits and are likely more related to each other than to other species.

19. There are two main theories regarding the migration of plants. 1. Plants that are closely related will migrate in a similar pattern because they share similar traits that are well-adapted for the environment, and 2. Plants that are closely related will migrate in a different pattern because they share similar traits that will compete with

each other, causing one to either go extinct or adapt new traits. Using your data and your phylogenetic tree, choose which theory is best supported in this activity. Explain, in detail, the reasons for your choice.
Answers will vary, but should include details supported by data in this activity.

20. What factors about the trees and pollen are ignored in this activity, but may lead to future research questions? Write a one page proposal describing a possible research question to explore in the future. Describe a possible hypothesis, how you would go about collecting data, and how you would illustrate your data.
Answers will vary, but should be well thought out and refer to information from this activity.

Acknowledgements
Data were obtained from the Neotoma Paleoecology Database (http://www.neotomadb.org/), and the work of the data contributors and the Neotoma community is gratefully acknowledged. This activity was created as part of the Kenan Fellows Program. Special thanks to Dr. Paul Harnik, NESCent scientist, who introduced me to Neotoma as part of our research project.