**Educational Modules for Climate Change, Paleoecology, and Biogeography**

A series of eleven modules have been developed for participants to use the Neotoma Paleoecology Database to learn about climate change, paleoecology, and biogeography. These modules are currently based on mammals but can easily be adapted to other organisms like coleoptera, plants, ostracodes, etc. There are two basic module types. One set of modules provides background information about the three topics. These modules can be used by learners who may not be familiar with the basic concepts of climate change, paleoecology, or biogeography. These modules provide the basic information required to work with the second group of modules that are a set of exercises that require queries of the Neotoma database. For instance, in the Paleoecology modules, relationships between climate (moisture and temperature) are discussed and illustrated (e.g. the latitudinal correspondence between temperature and the longitudinal correlation with temperature in the eastern United States) – see below.

**Figure 1**. Relationships between temperature and precipitation in the eastern United States with latitude and longitude respectively. Effective moisture is the amount of precipitation minus the amount of evaporation. Effective moisture is what generally controls the limits of distribution of organisms.

Then, the relationships between the modern distributions of mammals derived from the Neotoma database are compared to the climate parameters. It becomes apparent that in the eastern United States that the eastern and western limits of the species’ distributions are functions of moisture; whereas, the northern and southern ranges are related to temperature (see below). There is a brief discussion about underlying assumptions linking climate variables and species’ distributions and how they may sometimes be violated. For instance, the distribution of the prairie dog (*Cynomys ludovicianus*) may be controlled by climate as well as edaphic parameters [e.g., soil depth, particle size, and soil moisture]). At the end of each module there are a series of questions to reinforce the learning points. In addition, there are links to other web pages and literature that will provide further explanation of the principles.

**Figure 2**. Relationship between climate and modern biomes.

**Figure 3**. Limiting factors for the distribution of the black tailed prairie dog (*Cynomys ludovicianus*).

In the second modules, learners apply the knowledge they have gained from the background modules in conducting analyses of data taken from the Neotoma database. Each module begins with a statement about the process to be learned and then an example is provided. The learners develop a hypotheses (e.g., if the climate warms, then species X’s distribution will expand (north, south, east, or west). The participant then tests the hypothesis, by examining changes in the distribution of the species during different times of climate change based upon the GRIP climate data (e.g., transition from full glacial to late glacial or late glacial to late Holocene). A series of different mammal species are given to the student and they continue the exercise. If their, hypothesis is false, then the learner is asked why it failed. The learner is then taken to a file that then explains what potentially happened with their analysis. In some cases, multiple species may be involved in the exercise. Finally, based upon these analyses, the student is asked about the potential response of these species to future global warming.

**Figure 4**. Hypothesis testing.

For biogeographic analyses, students are asked to examine changes in species’ distributions through time. Various exercises then focus on when a species arrived in an area and how long it is maintained. With the addition of FAUNMAP II data that is currently, being uploaded, participants will be able to work with not only the late Quaternary, the last 20,000 years but will be able to go back through the Miocene to 30 million years ago. These exercises will involve rates of immigration and extinction for various mammal species.

Future work on all these modules will involve more exercises on conservation paleoebiology and more sophisticated analyses of groups of species (paleocommunities).