AMERICAN MUSEUM ᴏꜰ NATURAL HISTORY

Science Research Mentoring Program

MECHANISMS OF EVOLUTION

Students will be introduced to evolutionary theory and the mechanisms by which evolution occurs. Topics such as genetic mutation, gene flow, genetic drift, recombination, and natural selection will be taught in the context of micro- and macroevolution. Students will understand shared common ancestry or decent with modification, a hallmark of Darwin's Theory of Evolution and Natural Selection, and will build evolutionary trees to demonstrate these processes.

Session One: Introduction to Evolution and Variation

LEARNING OBJECTIVES

To understand that evolution means change in allele frequency—either small-scale observable change or large-scale gradual change—and that variation is necessary for such change to take place.

KEY TOPICS

- What is evolution?
- Microevolution vs. macroevolution
- Variation within and between species

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
15 minutes	**Assessment and Icebreaker**	Have students introduce themselves, and state something they know about evolution.
30 minutes	**Tour of Hall of Human Origins**	Introduce students to the traits that primates share and traits that are unique to different primate species (monkeys, apes, and hominids).
15 minutes	**Observations about variation in HHO**	Hall Activity: Make ten observations about living primates and/or extinct hominids. Alternative: Projecting images of primates and hominids, or any related species the instructor chooses to show as examples of variation between species.
30 minutes	**Discussion**	Students share observations/questions. Make inferences about variation within and between species and shared ancestry.
30 minutes	**In-Class Activities on within-species variation.** (Observable monogenic traits vary between humans.)	Monogenic Character Lab (below); Mendel; misconceptions about evolution.

Session Three: Introduction to Evolution and Variation (continued)

MATERIALS

- Syllabus handout
- Lab printouts

PREPARATION

If not using the hall — images of primates, hominids, or other species.

HALLS USED

Hall of Human Origins

AUDIO-VISUAL NEEDS

None required

HOMEWORK

None required

Session One: Introduction to Evolution and Variation: LAB
Introductory Monogenic Characters Lab

INSTRUCTIONS

YOUR NAME: PARTNER'S NAME:

Record your and your partner's phenotypes (observable traits) for each of the following monogenic characters. Hypothesize the possible underlying genotypes (specific allele combinations) for each character, for example: ZZ, Zz, or zz. Dominant traits are underlined.

DESCRIPTION	YOUR PHENOTYPE / POSSIBLE GENOTYPE		PARTNER'S PHENOTYPE / POSSIBLE GENOTYPE	
EARLOBES (Ee): Earlobes hang free or are attached to the side of the head. (Detached or Attached)				
DIMPLES (Dd): An indent in the check that appears when smiling. (Present or Absent)				
FRECKLES (Ff): Multiple brownish spots on face and arms. (Present or Absent)				
WIDOW'S PEAK (Ww): Hairline forms a distinct downward point above forehead. (Present or Absent)				
TONGUE ROLL (Tt): The ability to curl the sides of the tongue upward to form a tube. (Present or Absent)				
HANDEDNESS (Hh): The dominant hand used for activities such as writing. (Right or Left)				
THUMB CROSS (Cc): Order of thumb when hands folded with fingers interlocking. (R over L or L over R)				
THUMB EXTENSION (Xx): Backward bend of the thumb when extended. (Present or Absent)				
BITTER TASTER (Bb): Ability to taste bitterness. (Taster or Non-Taster)				

List similarities and differences between your and your partner's characteristics below.

Session Two: The Species Concept

LEARNING OBJECTIVES

To understand how to define a species and how speciation occurs.

KEY TOPICS

- Biological Species Concept
- Reproductive isolation
- Speciation
- Extinction

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
45 minutes	**Lab Activity: Use skulls to classify species**	Illustrates the limitations and subjectivity of morphological data for species classification; explains lumpers vs. splitters.
1 hour 15 minutes	**Pre-Darwinian essentialist concept vs. Biological Species Concept; speciation events**	Discuss reproductive isolation; punctuated equilibrium vs. gradualism; role of extinction in driving diversity (i.e. dinosaur extinction leading to radiation of primates).

MATERIALS

- Skulls for lab activity

PREPARATION

None required

HALLS USED

None required

HOMEWORK

None required

Session Three: Natural Selection

LEARNING OBJECTIVES

To understand how natural selection operates.

KEY TOPICS

- **Balancing selection**
- **Artificial selection**
- **Natural selection is not always perfect**

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
45 minutes	**Lab Activity: Use skulls to classify species**	Illustrates the limitations and subjectivity of morphological data for species classification; explains lumpers vs. splitters.
1 hour 15 minutes	**Pre-Darwinian essentialist concept vs. Biological Species Concept; speciation events**	Discuss reproductive isolation; punctuated equilibrium vs. gradualism; role of extinction in driving diversity (i.e. dinosaur extinction leading to radiation of primates).

MATERIALS

- **Activity printouts**

PREPARATION

If not using hall, gather materials for bean-eating birds activity.

HALLS USED

Bernard Family Hall of North American Mammals

HOMEWORK

None required

Session Three: Natural Selection: ACTIVITY
The Natural Selection of Bean-eating Birds

PURPOSE

To experience how the principle of natural selection works.

MATERIALS

- Paper cups, data sheet
- Beaks: forks (Prong-nosed rails), spoons (Spoon-billed waders), chopsticks (Cross-billed grebes)
- Beans: several hundred each of red beans (Slender norbs), white beans (Pot-bellied lum lums), black beans (Rounded toubs), pumpkin seeds (Flat-faced woogies)

PROCEDURE

1. Divide the class into three groups, each representing a bird species. Each "bird" takes the tool that represents its beak shape (spoon, fork, etc.) and a paper cup to represent the bird's stomach.

2. Spread all the beans onto a flat surface, which will represent a simulated environment where 100 beans of each type are dispersed.

3. The birds gather around, and when given the signal to "Hunt!" they , collect beans and put them into their cups for one minute. They then count and record data by species.

4. Birds that collect fewer than 20 beans (sufficient energy to survive and reproduce) die. ("Dead" birds are "resurrected" as the progeny of surviving birds.)

5. Tally how many of each type of bean are left on the table. For each bean species, the number of beans will double with each generation as the surviving beans reproduce. So, for example, if there are 20 black beans left, add in another 20 before the next round of hunting.

6. Determine how many offspring the surviving birds of each species produce by dividing the number of survivors by 2, and adding that many individuals back into the hunt (we'll assume an even sex distribution and one offspring per pair).

7. Repeat steps 3 to 6 for a total of 3 generations.

8. Simulate an environmental shift by changing the number of beans at the beginning (e.g. decrease the number of beans to show the effects of a drought year on the bean species) and repeat the experiment again, starting with step 1.

ACTIVITY: The Natural Selection of Bean-eating Birds

RULES

- Birds may only touch food with their beaks. NO hands!
- Food must make it to the stomach to count.
- Stomachs may NOT touch the ground at any time.
- Do NOT hurt other birds (you can help each other)
- Do NOT touch other birds' stomachs.

QUESTIONS

1. Did any bird species become extinct? If so, which one(s)?

2. Which bird species would be considered the most fit?

3. Did any bean species become extinct? If so, which one(s)?

4. Which bean species would be considered the most fit?

5. How do environmental conditions influence the survival rate of bird and/or bean species?

6. How does this experiment relate to naturally occurring animal populations?

7. How might a group of organisms in nature avoid extinction due to competition?
   (Hint: Darwin's finches are a great example).

Session Three: Natural Selection: DATA SHEET

Natural Selection of Beans

Environment 1: Sand Dunes

INSTRUCTIONS

Record the number of beams COLLECTED, of each color, and by each group.

1ST GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

2ST GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

3RD GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

DATA SHEET: Natural Selection of Beans (continued)

Environment 2: Mud Flats

INSTRUCTIONS

Record the number of beams COLLECTED, of each color, and by each group.

1ST GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

2ST GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

3RD GENERATION	Cross-billed grebes (CX)	Spoon-billed waders (S)	Prong-nosed rails (F)	TOTALS
Pot-bellied lum lums (W)				
Slender norbs (R)				
Rounded toubs (B)				
Flat-faced woogies (G)				
TOTALS				

Session Four: Darwin Day

LEARNING OBJECTIVES

To understand how pre-Darwinian naturalists explained variation within a species, and how Darwin's observations changed the way scientists viewed species' adaptations to different environments.

KEY TOPICS

- Intro to adaptation, variation, and speciation
- Pre-Darwinian thought
- Darwin's influences (Lamarck, Malthus, Lyell, etc.)
- What is an adaptation and what role does it play in survival?
- Darwinian theory of common descent with modification, via natural selection

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**Context of evolutionary thought**	Explanation of pre-Darwinian thought, Darwin's influences and observations, and Darwin's theory of common descent with modification, via natural selection.
60 minutes	**Adaptations**	Students explore the Spitzer Hall of Human Origins to find adaptive traits and identify the specific environmental pressure that shaped these traits. Alternative: Project images of species in their natural habitats and ask students to identify the environmental pressures that shaped their observable adaptive traits

PREPARATION

If not using the hall, images of species to use to identify adaptive traits.

HALLS USED

Spitzer Hall of Human Origins

Session Five: Mechanisms by which Evolution Occurs

LEARNING OBJECTIVES

To understand sources of variation and how it is maintained or redistributed in a population

KEY TOPICS

- Mutation
- Sexual recombination
- Genetic Drift
- Gene flow
- Natural Selection

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**Assess prior knowledge of genetic mutations, recombination, gene flow, genetic drift, natural selection**	Explain exceptions to Hardy-Weinberg: random mutations – deleterious, advantageous, neutral – as only source of novel variation; gene flow increase variation within a population but decreases variation between populations; drift decreases variation within a population but increases variation between populations; natural section is editor of variation; criteria for natural selection to occur
60 minutes	**In-Class Activity:** **Population Genetics-Mechanisms of Evolution**	Students learn how changes in allele frequency affect population changes. Colored beads represent alleles in a population and simulate how different evolutionary forces cause allele frequencies to shift. Use the handout.

MATERIALS

- Printouts of activity, red and white beads, cups

Session Five: Mechanisms by which Evolution Occurs: WORKSHEET

Population Genetics: The Forces of Evolution

INTRODUCTION

Population genetics is the study of allele frequency distribution and change under the influence of the four evolutionary forces: natural selection, genetic drift, mutation, and gene flow. In this lab, you will study the different forces of evolution. You will also examine how these forces can effect the frequencies of certain alleles in a population.

EXERCISE 1: FORCES OF EVOLUTION

Evolution is a change in allele frequencies from one generation to the next caused by several different forces. Your lab instructor will discuss how the four forces of evolution and non-random mating act on a population. Make notes if necessary.

1. Mutation

2. Natural Selection

3. Genetic Drift

4. Founder effect (a specific type of genetic drift)

5. Gene flow

6. Natural Selection

WORSHEET: Population Genetics: The Forces of Evolution (continued)

EXERCISE 2: POPULATION GENETICS

A. Genetic Drift

We will use red and white beads to represent different alleles in a population. The red beads will represent a dominant allele, R, and the white beads will represent a recessive allele, r.

You'll need one container that holds 24 white beads and 24 red beads (48 beads total). Shake the container several times to mix the beads thoroughly. Draw out two beads. They represent a new individual, who has inherited one allele from each parent. For example, if you draw a red bead and a white bead, you'll have formed an individual with the genotype Rr. This individual is a heterozygote, with the dominant phenotype. If you draw two white beads, you will have formed an individual with the genotype rr, a homozygote with the recessive phenotype.

	RR	Rr	rr
# of individuals			

In a theoretical population that is infinitely large, mating is random, and where no evolution is taking place (i.e. none of the forces of evolution are acting on the population), certain genotypic ratios will always be held constant. Twenty-five percent will be homozygous dominant (RR), 50% will be heterozygous (Rr), and 25% will be homozygous recessive (rr). These are known as the expected genotypic ratios. These ratios are expected because each allele has an equal chance of being choice in a particular mating. In nature, however, expected genotypic ratios are uncommon because populations are not infinitely large, mating is rarely random, and evolution is always occurring.

1. What is the expected phenotypic ratio for this population?

2. What is the actual phenotypic ratio? Genotypic ratio?

3. Why do you see a difference between the expected and actual genotypic and phenotypic ratios?

WORKSHEET: Population Genetics: The Forces of Evolution (continued)

EXERCISE 2: POPULATION GENETICS (CONTINUED)

B. Selection against the recessive phenotype

In the previous exercise all of the genotypes had equal fitness, meaning that they all had an equal chance of reproducing. In real populations, this is seldom the case. Some genotypes are lethal or can cause significantly decreased fitness. For example, cystic fibrosis is a recessive genetic disease that can affect lung and digestive functions and is life-threatening. Sickle cell anemia is another serious recessive genetic disease. For this exercise, the recessive phenotype is lethal, so those individuals do not survive to reproduce.

Start with 24 red beads and 24 white beads in your cup. Select two beads without looking. DO NOT return the beads to the original container. Record each pair you draw (RR for two red beads, Rr for a red and a white bead, rr for two white beads). Keep each pair you have drawn separate. Make a total of 24 draws. Your cup should be empty. This represents the first generation.

To obtain the second generation, place all of the beads that were drawn as RR or Rr back into the cup. Leave out the individuals that were drawn as rr back, since these individuals have the lethal genotype and cannot reproduce. Repeat this process for five generations.

	RR	Rr	rr
1st generation			
2nd generation			
3rd generation			
4th generation			
5th generation			

1. Did the dominant allele "fix" in the population? In other words, was there a point in the experiment where there were no more recessive alleles left in the population?

2. If so, how many generations did it take for this to occur?

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WORKSHEET: Population Genetics: The Forces of Evolution (continued)

EXERCISE 2: POPULATION GENETICS (CONTINUED)

C. Selection against the dominant phenotype

There are many lethal recessive conditions, along with a few that are dominant. This exercise explores what occurs when the dominant allele is lethal.

Assume that the dominant phenotype is lethal. Repeat the previous exercise. Leave RR or Rr combinations aside, and place rr individuals back into the cup for the next generation.

	RR	Rr	rr
1st generation			
2nd generation			
3rd generation			
4th generation			
5th generation			

1. How many generations did it take for the recessive allele to "fix" in the population? In other words, was there a point in the experiment where there were no more dominant alleles left?

2. Why did it take less time for the recessive allele to become fixed than it did for the dominant allele to become fixed in the previous exercise?

WORKSHEET: Population Genetics: The Forces of Evolution (continued)

EXERCISE 3: SICKLE CELL ANEMIA

Some individuals living in parts of the tropics (notably West and Central Africa) suffer from sickle cell anemia. Because they have deformed (sickled) red blood cells, their blood cannot properly transport oxygen. Sickle cell anemia is determined by two alleles, A and S. People who have the AA genotype have normal red blood cells. Those that have the SS genotype develop extreme sickle cell anemia and normally die before puberty. Heterozygous (AS) people have both normal and sickled red blood cells, and experience mild anemia.

The distribution of the sickle cell trait correlates with that of malaria, a parasitic disease carried and spread by mosquitoes. (See maps.) Some degree of sickling can kill the malarial parasite. Heterozygotes (AS) contract malaria less frequently than homozygotes (AA).

Distribution of Malaria   **Distribution of Sickle Cell Allele**

The first map shows the distribution of malaria across Africa, Southern Europe and Western Asia. The dark gray areas represent places were malaria is present. The second map shows the distribution of the sickle cell anemia allele. The darkest gray areas represent the highest concentration of sickle cell alleles.

1. What genotype is advantageous where malaria is prevalent? Why?

2. What evolutionary force is acting on these populations?

3. In areas where malaria is prevalent, the AA and SS genotypes are disadvantageous — one leaves you susceptible to malaria and the other gives you sickle cell anemia. If both genotypes are selected against, why do they exist in high frequencies in these populations?

Session Six: What is in the Genome?

LEARNING OBJECTIVES

To understand how to represent common ancestry based on shared derived traits.

KEY TOPICS

- Synapamorphies (shared derived traits)
- Autapomorphies (unique derived traits)
- Homologies
- Common ancestry
- Cladistics

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**Hall Activity: 4th Floor Hall of Extinct Mammals, Cladistics activity (pdf)**	Introduce students to shared derived traits and building evolutionary trees based on these traits. Use the glossary.
		Alternative: Students can use internet research to complete the attached activity, "4th floor Fossil Hall" and rename the topic extinct vertebrate cladistics.
60 minutes	**Tree Thinking Activity**	Students will explore several ways of constructing and understanding phylogenetic trees.

MATERIALS

- Printouts of activities

Session Six: Mechanisms by which Evolution Occurs: HANDOUT

Phylogenetic Tree Glossary

autapomorphy	A derived character state unique to a particular taxon
clade	A group of organisms that includes the most recent common ancestor of all of its members and all of the descendants of that most recent common ancestor. From the Greek word "klados", meaning branch or twig.
cladogram	A diagram, resulting from a cladistic analysis, which depicts a hypothetical branching sequence of lineages leading to the taxa under consideration. The points of branching within a cladogram are called nodes. All taxa occur at the endpoints of the cladogram.
derived	Describes a character state that is present in one or more but not all, of the subclades of a clade under consideration. A derived character state is inferred to be a modified version of the primitive condition of that character, and to have arisen later in the evolution of the clade. For example, "presence of hair" is a primitive character state for all mammals, whereas the "hairlessness" of whales is a derived state for one subclade within the Mammalia.
homoplasy	A collection of phenomena that leads to similarities in character states for reasons other than inheritance from a common ancestor. For example, functional convergence in structures adapted to similar environments (e.g. wing of a bird and a bat).
homology	Two structures are considered homologous when they are inherited from a common ancestor which possessed the structure.
phylogenetics	Field of biology that deals with the relationships between organisms. It includes the discovery of these relationships and the study of the causes behind this pattern.
plesiomorphy	The ancestral character state
primitive	Describes a character state that is present in the common ancestor of a clade. A primitive character state is inferred to be the original condition of that character within the clade under consideration. For example, "presence of hair" is a primitive character state for all mammals, whereas the "hairlessness" of whales is a derived state for one subclade within the Mammalia.
symplesiomorphy	A shared ancestral character state
synapomorphy	A shared derived character state

Session Seven: Primate Origins

LEARNING OBJECTIVES

To apply understanding of homologies and cladistics to the Primate Order.

KEY TOPICS

- Strepsirhines
- Haplorhines
- Character matrix

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
30 minutes	**Introduction to the Primate Order – assess prior knowledge of Primate shared derived traits, and the Primate Sub-Orders**	Classification and characteristics of Primate Order, and Sub-Orders Strepsirhini and Haplorhini.
60 minutes	**Hall Activity: Primate Hall, 3rd Floor**	Students choose taxa and traits and complete a binomial character matrix. Alternative: See the "Primate Hall Character Matrix". Students can look at images or do internet research to fill in this matrix. Also, instructors have some flexibility in terms of choosing the species/taxa for this activity.
20 minutes	**Wrap-up**	Discuss what traits were used, and subjectivity of potential trees.

MATERIALS

- Printouts of activity; if using alternative, use images of primates for activity.

HALLS USED

Hall of Primates

Session Eight: Tree Building

LEARNING OBJECTIVES

To understand how to build an evolutionary tree based on a character matrix.

KEY TOPICS

- Using Genbank and other sequence databases
- Independent project: collecting gene sequences for alignment

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**Classroom Activity: Tree Building**	Students import their Primate character matrices from last class into a tree-building program to generate evolutionary trees based on the chosen taxa and characters. Instructions can be found below in "Tree Building with Mesquite".
30 minutes	**Hall Activity: Primate Hall, 3rd Floor**	Students return to Hall of Primates to compare their trees with those displayed in the Hall. Alternative: Compare to published trees or use the Tree of Life website (http://tolweb.org/tree/).
20 minutes	**Intro to Human Evolution**	Transition to Superfamily Hominidae.

MATERIALS

- Printouts of activity, computers for students

PREPARATION

If using alternative, computer access for students to compare to published trees or Tree of Life website; ensure Mesquite loaded on all computers.

HALLS USED

Hall of Primates

Session Eight: Tree Building

Activity: Tree Building with Mesquite

PROCEDURE

(written for software version 2.5, build j77)

1. File -> NEW, name your file "Primate Tree", then save.

2. "New File Options" window will pop up:
   - check "Make Taxa Block"
   - enter the number of species you have in your analysis
   - check "Make Character Matrix"
   - hit "OK"

3. "New Character Matrix" window will pop up:
   - enter the number of characters (or traits) in your analysis
   - Type of Data should be "Standard Categorical Data"
   - hit "OK"

4. Enter the data you collected in the Primate Hall into the data matrix. The species names are written on the vertical axis, and the traits go horizontally across the top of the matrix. The data itself should consist only of 1's and 0's.

5. Go up to the "Taxa&Trees" tab -> select "Make New Trees Block from" -> select "Cluster Analysis"

6. "Source of distance for Cluster Analysis" window will pop up -> select "Distances from Character Matrix", hit "OK".

7. "Distance calculator" window will pop up -=> select "Uncorrected Distance (General)", hit "OK".

8. "Clustering method" window will pop up -> select UPGMA (unweighted pair group method with arithmetic mean).

9. MAXTREES window will pop up -> enter "100" into the window.

10. "Separate Thread?" window will pop up -> select "NO".

11. "Trees ready" window will pop up -> select "YES".

Trace Character History

This feature will allow you to trace the ancestral state of each trait.

1. You should be in the tree window, able to view your tree.

2. Go up to the "Analysis" tab at the top -> select "Trace character history."

3. "Ancestral State reconstruction method will pop up -> select "Parsimony Ancestral States", hit "OK".

Session Nine: Human Origins

LEARNING OBJECTIVES

To understand how hominids and anatomically modern humans evolved.

KEY TOPICS

- Hominids
- Genus Homo
- Out of Africa
- Mitochondrial DNA

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**Hall Activity: Tour of the Hall of Human Origins**	Discuss shared derived traits of Apes and hominids, Australopithecine evidence of bipedalism, early Homo species making tools, first dispersal of genus Homo, competing models for the origins of modern humans, genetic evidence. (Note: this discussion can be done without touring the hall)
60 minutes	**Lab Activity: Exploring Human Origins**	Students use the handout and collect data from skull casts, early stone tools, and DNA sequences, as evidence for physical, cultural, and genetic evolution. If needed, use on-line resources such as Smithsonian's Human Evolution Interactive Timeline (http://humanorigins.si.edu/evidence/human-evolution-timeline-interactive) and E-Skeletons (http://www.eskeletons.org) to investigate human origins.

MATERIALS

- Printed handouts for lab activity; skull cases, stone tools, DNA sequences; if using alternative activity, computers for students

HALLS USED

Spitzer Hall of Human Origins

Session Ten: Neanderthals: Who were they and what caused their extinction?

LEARNING OBJECTIVES

To understand the genetic underpinnings of specific Neanderthal traits inferred from DNA evidence. Secondly, to explore what factors cause species extinction.

KEY TOPICS

- SNP's
- Multiple sequence alignment
- Ancient DNA
- Extinction

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
75 minutes	**Activity: Neanderthals in the flesh**	Infer physical characteristics of our extinct relatives from ancient DNA.
45 minutes	**Discussion**	See group of handouts for this activity. Discuss Neanderthal activity and various extinctions hypotheses: climatic Shifts, competition, and/or admixture with Homo sapiens.

MATERIALS

- Printouts of all documents in Neanderthals in the Flesh activity

Session Eleven: Mammoths and Other Mammals

LEARNING OBJECTIVES

To understand how the environment and random factors contribute to the extinction of a species.

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
60 minutes	**In Class Activity: Mammoth Extinction Game**	Explore how environmental pressures and random chance can contribute to species extinction. Each student receives three pennies and flips each coin to reveal a pattern, which corresponds to a chart determining death, life, or reproduction. Students record their results together in a bar chart on the smart board. Game continues for 10 generations.
60 minutes	**Hall Activity: Wallace Wing of Mammals and Their Extinct Relatives**	Students go to the Wallace Wing of Mammals and Their Extinct Relatives, choose ten species and record when and where they lived. Then they return to HHO to determine which species lived alongside Homo sapiens, and hypothesize whether humans played a role in their extinction.
		Alternative activity: based on the Mammoth Extinction game, have students come up with their own models or testable hypotheses for species extinction. Then have them choose an extinct species to research online, and apply their model or hypotheses to explain their chosen species' extinction.
		Questions: Does it apply? How universal is your model? How can you change it to apply to species extinction in general?

MATERIALS

- Printouts of mammoth extinction game, enough dice for all groups; if using alternative activity, computer access for students

HALLS USED

- Wallace Wing of Mammals and Their Extinct Relatives
- Spitzer Hall of Human Origins

Session Twelve: Final Project

LEARNING OBJECTIVES

Final Project will consist of assembling a full *Homo sapiens* and *Pan troglodytes* skeleton from disarticulated bones. Students will work in groups to decipher the differences between bones of each species, and determine where each bone belongs on the fully articulated skeleton.

If skeletons aren't available, this activity can be replaced with a final tree building program. Students work in groups to:

- choose 10 different species and traits

- build and fill-in a character matrix

- use the matrix to build a phylogenetic tree showing relationships between their chosen species

- give a presentation explaining the relationships

MATERIALS

- Disarticulated bones; OR computers for students to do alternative activity

PREPARATION

None required

HALLS USED

N/A

AUDIO-VISUAL NEEDS

None required

HOMEWORK

None required