American Museum of Natural History

Science Research Mentoring Program

BIODIVERSITY: TREE OF LIFE

This course introduces students to the diversity of major groups of organisms and their evolutionary relationships. Students will be able to understand concepts used in studying biodiversity, recognize major groups on the tree of life, and understand the link between biodiversity and evolution.

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Session One: What is Biodiversity?

LEARNING OBJECTIVES

Students should be able to define biodiversity and explain the current state of biodiversity research, understand the hypotheses for the origin and evolution of life on Earth, and explain the planet's geologic history and how it relates to the development and diversification of life on Earth.

KEY TOPICS

- Biodiversity
- Origin of Life
- Prokaryotes

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
30 minutes	**Course Introductions and Icebreaker**	Instructor will 1) take attendance and hand out and review the syllabus; 2) Introduce instructors; 3) Ask students to introduce themselves and their interests.
45 minutes	**Lesson: What is Biodiversity?**	Instructor will introduce the origins and development of biodiversity science, key terms (populations, species, communities, ecosystems, endemism, etc.), and current state of research.
45 minutes	**Gottesman Hall of Planet Earth**	Instructor will split students up into 5 teams, pass out the worksheet, and explain how Earth's dynamic geologic history enabled life to develop and diversify. As teams walk through hall, each will answer a set of questions (Team 1: How has the earth evolved?; Team 2: Why are there ocean basins, mountains, and continents?; Team 3: Why are there ocean basins, mountains, and continents?; Team 4: Why is the earth habitable?; and Team 5: What causes climate and climate change?). Back in the classroom, discuss the answers and how Earth processes have led to the biodiversity we see today. If time does not allow, begin the next class with this discussion. ALTERNATIVE: If the class does not have access to museum halls, use the same worksheets and have students use this website: www.windows2universe.org/earth/earth.html

Session One: What is Biodiversity? (continued)

MATERIALS

- Notecards
- Syllabus handout
- Worksheet for walking through hall (HallPlanetEarthWorksheet.pdf)

PREPARATION

If not using the hall, use computer access for students.

HALLS USED

Gottesman Hall of Planet Earth (1st Floor)

AUDIO-VISUAL NEEDS

Projector

Session Two: Biodiversity and Species Models

LEARNING OBJECTIVES

Students will be able to understand what speciation is and how species originate, explain how genetics and phenotype contribute to speciation, define the barriers to viable reproduction between species, define species based on historical species models, and define biogeography.

KEY TOPICS

- How do species form?
- Species concepts

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
30 minutes	**Lesson: Studying Species and Speciation**	What is a species? Define speciation and reproductive isolation.
30 minutes	**Activity: Species Models**	Jigsaw; species concepts (see activity directions).
30 minutes	**Lesson: Importance of Biogeography**	Modes of speciations; biogeography.
30 minutes	**Activity: How are species classified in different phyla?**	Walk through the Hall of Biodiversity (see directions).

MATERIALS

- Species concepts pdf (Session 2 - species.pdf)
- Worksheet for Hall of Biodiversity/classroom exercise

HALLS USED

Hall of Biodiversity

AUDIO-VISUAL NEEDS

Computer, projector, whiteboard, markers

Session Two: Biogeography and Species Models: ACTIVITY

Jigsaw Species Models

OVERVIEW

Students will work in groups of 3-4 and read an assigned section from species.pdf. They'll present an overview of their species model to the class.

TIME FRAME

30 minutes

PROCEDURE

- Each table will receive one species concept to review and present to the class.
- Students spend ten-15 minutes reading and prepare to present the information learned to the class.
- Everyone reads Section I
- Group 1 reads Section III.A and III.B
- Group 2 reads Section IV
- Group 3 reads Section V.A & B
- Group 4 reads Section VI.C
- Group 5 reads Section VII.A
- Everyone reads Section VIII
- The instructor should circulate the room and use formative assessment to gauge progress and completion.
- Teams present an overview of each species concept to the class, explaining what basis is used to define species.
- Instructors will lead group discussion about defining species, asking specifically, "Are species concepts real?"

Session Two: Biogeography and Species Models: ACTIVITY

How Are Species Defined Within Major Phyla?

OVERVIEW

Working individually or in pairs, students will describe characteristics of major phyla in the Hall of Biodiversity.

Alternative: Select phyla ahead of time and provide information for students to complete the exercise, or provide computer access for students to look up information on an assigned phylum.

TIME FRAME

30 minutes

PROCEDURE

- The instructor will ask students to quickly split up or divide into pairs.
- Pass out the questions and demonstrate activity with one major phylum.
- The instructor should circulate the room and use formative assessment to gauge progress and completion.
- Students will take notes, and answer guided questions
- If time permits, discuss results back in classroom. Otherwise, discuss results at the beginning of Session 4.

Session Two: Biogeography and Species Model: WORKSHEET

Questions for the Hall of Biodiversity

QUESTIONS FOR THE HALL OF BIODIVERSITY

Choose a phylum on the "spectrum of life" wall in the Hall of Biodiversity.

1. **Describe the phylum's distinguishing characteristics:**

2. **List representative species from the major groups within the phylum:**

3. **Describe these organisms' habitats:**

4. **Discuss their body plan and how they have adapted to their environment:**

5. **What are their behavioral strategies? (For example: how do they reproduce, gather food, move, and socialize?)**

Session Three: Taxonomy and Classification

LEARNING OBJECTIVES

Students will be able to describe the fundamentals of taxonomical methodology, understand how species are named, classified and identified, build a dichotomous keys, and use a dichotomous key to identify plant species.

KEY TOPICS

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

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
30 minutes	**Lecture: Classical Methods for Naming Organisms**	Introduction to Linnaean classification, nomenclature rules, and identification.
30 minutes	**Activity: Practice Dichotomous Key Construction**	Build a key from a list of 9 random objects. Key out each object until it stands alone.
30 minutes	**Activity: Identifying Unknown Tree Species**	What leaf is it? Use the leaf key and leaf terms to identify 13 samples.

MATERIALS

- Lists of objects for dichotomous key exercise
- Tree leaves
- Tree identification key (Session 3 - LeafKey_and_Terms.pdf)

AUDIO VIDEO NEEDS

Project for PowerPoint presentation

Session Three: Taxonomy and Classification: ACTIVITY

Build Your Own Dichotomous Key

OVERVIEW

When student first enter the classroom the instructor asks them to write down a random physical object. They can be creative.

TIME FRAME

30 minutes

PROCEDURE

- The instructor will ask students to work in groups at tables, and to combine the names of their objects. There should be at least 4 words.
- Groups then build a dichotomous key that splits each word into individual units.
- Dichotomous keys split groups multiple times, but each individual step should only split based on two mutually exclusive descriptions.
- Students write their key on the board and present to the class.
- Instructors should encourage students to participate in group discussion and critique each others' keys.
- Instructors should point out that keys should be designed for use by a large audience and descriptions should be clear. Objective rules, like physical measurements, are ideal.

Session Three: Taxonomy and Classification: ACTIVITY

What Leaf Is It?

OVERVIEW

Students will work in teams to identify a variety of unknown leaves.

TIME FRAME

60 minutes

PROCEDURE

- The instructor will pass out the leaf dichotomous key guide and review glossary terms specific to plants.
- Each group gets a set of unidentified specimens.
- The instructor should use one example to show how to use the key.
- Each group identifies all leaves.
- Instructors review the correct answers.

Session Four: Evolution Trees

LEARNING OBJECTIVES

Students will be able to define and read evolutionary trees, map character steps on a tree, and use the concepts of monophyly, paraphyly, and polyphyly to recognize such groups in a given tree.

KEY TOPICS

- Phylogenetic methods
- Vocabulary used in phylogenetics
- How to read a tree
- Character transformations

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
15 minutes	**Lecture: Evolutionary Theory**	Introduction to evolutionary theory, concept of homology, tree reading, morphological and molecular data, and phylogenetic methods.
15 minutes	**Assessment**	Instructors pass out a short worksheet to gauge students' prior knowledge: "Tree thinking assessment".
15 minutes	**Review Assessment**	Instructors discuss answers and clear up any misconceptions.
15 minutes	**Finish Lecture: Evolutionary Theory**	Introduction to evolutionary theory, concept of homology, tree reading, morphological and molecular data, phylogenetic methods.
25 minutes	**Activity: Tree Reading and Character Mapping**	Using character matrix to score trees.
5 minutes	**Activity: Tree Reading and Character Mapping**	Review character mapping and find the most parsimonious tree.
30 minutes	**Primate Hall Activity**	Take the students to the Hall of Primates to fill out their matrix OR Instructor can use photos to illustrate the species on the worksheet so students can fill out the matrix without access to the halls.

Session Four: Evolutionary Trees (continued)

MATERIALS

- Tree-thinking assessment (Session 4 - TreeThinkingAssessment1.pdf)
- Primate Phylogenetics Exercise (PrimateDataMatrixExercise.docx)
- Two mammal skulls: one non-primate and one monkey
- Inferring phylogenies, by Joe Felsenstein
- If not using Primate Hall, illustrative photos of the species on the worksheet

PREPARATION

None (or finding photos of the species on the worksheet)

HALLS USED

Hall of Primates

AUDIO-VISUAL NEEDS

Projector

HOMEWORK

Finish primate data matrix exercise

Session Four: Evolutionary Trees: ACTIVITY

Tree Reading and Character Mapping

OVERVIEW

Students will work in teams of 3 to 4 to map character transformations to their tree.

TIME FRAME

30 minutes

PROCEDURE

- Instructor will explain the coding of the matrix.
- Instructor should draw out 6 different trees (Inferring Phylogenies, by Joe Felsenstein, pg. 3) and assign one to each group of students. Make sure one tree drawn is the correct one (Lamprey, (Shark, (Salamander, (Lizard (Tiger, (Gorilla, Human))))))).
- Ask students to map the character transformations on their tree. Have them count the number of changes for each tree (L= length).
- A representative from each group shows their transformations and lengths on the white board.
- Instructors go over discussion questions:

  Which tree is the most parsimonious?

  How long is it?

  Which characters are synapomorphies in the context of the maximum parsimony tree?

ACTIVITY: Tree Reading and Character Mapping (continued)

DATA MATRIX

Students will work in teams of 3 to 4 to map character transformations to their tree.

	Jaws	Lungs	Amniotic Membrane	Hair	No Tail	Bipedal
Lamprey	0	0	0	0	0	0
Shark	1	0	0	0	0	0
Salamander	1	1	0	0	0	0
Lizard	1	1	1	0	0	0
Tiger	1	1	1	1	0	0
Gorilla	1	1	1	1	1	0
Human	1	1	1	1	1	1

Session Four: Evolutionary Trees: ACTIVITY

Tree Reading and Character Mapping

OVERVIEW

Students will work individually in the Hall of Primates to score a data matrix and build trees and identify length for homework.

TIME FRAME

30 minutes + Homework

DATA MATRIX

See 'PrimateDataMatrixExercise.docx'

PROCEDURE

- Instructor will pass out and explain the exercise:

  Fill out the data matrix using the specimens you observe in the Hall of Primates. Do not add taxa or characters. You may have to get some of the information from the diorama text or the large tree on the back wall.

- Instructors then take students to the hall where they should circulate and answer questions as necessary.

- For Homework

  As homework, you will draw four unique, rooted (using the specified outgroup), bifurcating tree shapes for these taxa. That set of trees is not the entire set of possible trees, but it doesn't matter— just pick four. They may seem weird or "wrong", but, again, it doesn't matter as long as they are four different trees.

  On each of those four trees map all the character transformations (try to minimize homoplasy) and record the Parsimony score (or tree length) for each of the four trees. Bring those trees, with their character transformations and score to the next class.

Session Five: Finish Tree Thinking

LEARNING OBJECTIVES

Students will be able to understand fundamental concepts and methods of phylogenetic systematics, use alignment/phylogenetics software packages, analyze DNA sequences and build a phylogenetic tree, and compare the performance of two different alignments derived from the same dataset.

KEY TOPICS

- Phylogenetic methods
- Vocabulary used in phylogenetics
- Structure of DNA

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
20 minutes	**Review Primate Hall Tree activity**	Review character mapping exercise from previous lesson. Choose the correct tree.
20 minutes	**Lecture: Phylogenetics**	Instructors will review some of the concepts from the previous lesson (monophyly, paraphyly, polyphyly) and introduce molecular techniques (DNA extraction, PCR, DNA sequencing, DNA barcoding), and how they're used in phylogenetics.
20 minutes	**Activity: Phylogenetics quiz**	Instructors will pass out the Tree thinking assessment 2 and review answers with students to address any misconceptions.
20 minutes	**Lecture: Computer Software used in Phylogenetics**	Phylogenetics and DNA alignment. The instructor will show how to download DNA from PubMed, align it with Mega5, and build a simple tree.
40 minutes	**Activity: DNA Alignment**	Download Mega5, Alignment and Phylogenetic inference.

Session Five: Finish Tree Thinking (continued)

MATERIALS

- Computers for students
- Tree assessment 2 (Tree-thinking-quizz2.pdf)
- Alignment and Phylogenetic inference handout for students (Alignment exercise.pdf)

PREPARATION

Install Mega5 and DNA FASTA file on student computers

AUDIO-VISUAL NEEDS

Computer and projector

HOMEWORK

Answer questions from alignment activity

Session Five: Finish Tree Thinking: ACTIVITY

Alignment and Phylogenetic Inference

OVERVIEW

The purpose of this exercise is to gain familiarity with an alignment/phylogenetics software package and to compare the performance of two different alignments derived from the same dataset.

TIME FRAME

40 minutes

MATERIALS

Computers for either each table or each pair of students. Mega5 software.

PROCEDURE

Instructors will pass out the assignment and computers. Students should follow directions on 'Alignment exercise.pdf' and instructors should circulate, troubleshooting and answering questions.

For homework, students should answer the questions at the end of the worksheet.

Session Six: Micro-Biodiversity

LEARNING OBJECTIVES

Students will be able to identify prokaryotes and unicellular eukaryotes, identify the parts of a microscope, prepare a microscope slide for viewing, use a microscope at all focus levels, and survey a sample of pond water in order to identity microorganisms.

KEY TOPICS

- Phylogenetic methods
- Vocabulary used in phylogenetics
- Structure of DNA

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
20 minutes	**Review: Phylogenetics**	Review alignment and phylogenetic inference activity from session 5.
20 minutes	**Lecture: The Base of the Tree of Life**	Introduction to prokaryotes, unicellular eukaryotes, and select extremophiles.
1 hour	**Activity**	Finding, observing, and identifying organisms in pond water.
20 minutes	**Discussion**	What can we learn from the study of microscopic organisms? Instructors should walk through each question: 1. How many different kinds of organisms have you seen? Do they belong to the same group? 2. Which organisms were most abundant? 3. Do they all swim in the same way? How do different organisms swim? 4. Is anything in the field not moving? What could it be?

Session Six: Micro-Biodiversity (continued)

MATERIALS

- Pond water from turtle pond
- Microscopes
- Slides and coverslips
- Dissection kits
- Pondcritter worksheet (Turtle Pond Water Lab.docx)
- Pondscum reading (pondscum.pdf)

PREPARATION

Collect pond water 24 hours prior to class.

AUDIO-VISUAL NEEDS

Computer and projector

HOMEWORK

Finish questions at the end of their worksheet.

Session Six: Micro-Biodiversity: ACTIVITY

Turtle Pond Water Lab

OVERVIEW

Students will investigate the diversity of life within a drop of pond water.

TIME FRAME

60 minutes

MATERIALS

Microscopes for each table or pair of students, slides, coverslips, pipettes, 'Turtle Pond Water Lab' worksheet, pond water.

PROCEDURE

Instructors will pass out the assignment and introduce students to using a microscope. They should make sure to cover all safety procedures. Students should follow 'Turtle Pond Water Lab' directions step by step. Instructors should circulate the room answering questions, helping to identify microorganisms, and paying attention to how students treat the equipment. Students will look for organisms sequentially, from low power to high power.

For homework, students should answer the questions at the end of the worksheet.

Session Six: Micro-Biodiversity: LAB

Turtle Pond Water Lab

Names:

With your partner, work through this lab procedure making notes and sketches. Then, answer the discussion questions.

PROCEDURE

1. Use a pipette to extract a water sample from the container. Put a very small drop of pond water on a slide. Place a cover slip over it.

   a. Where did the sample come from: top, middle, or bottom of the container?

   b. Explain why it would make a difference:

2. Now, look at the drop of water through the microscope under low power. Sketch what you see:

3. Now, look at the drop of water in your microscope under medium power. Sketch what you see:

LAB: Turtle Pond Water (continued)

4. Now, look at the water under high power. Once you see a living thing, follow it closely and sketch it on the following page. Draw some of the paths it takes as it moves across the field of your microscope. Then use the guide to try to identify and name it.

5. On the following page, sketch the shape of the kind of microorganism that seems most common.

6. Also sketch the largest organism you see.

7. Finally, sketch and identify as many organisms as you can.

LAB: Turtle Pond Water (continued)

SKETCH

LAB: Turtle Pond Water (continued)

PROCEDURE

1. Do all the organisms you see swim in the same way? If not, how do they swim?

2. How many different kinds of organisms have you seen? Do they come from the same groups?

3. Is anything not moving? What could it be?

4. Which organisms were most abundant?

Session Seven: Tools for Studying Biodiversity

LEARNING OBJECTIVES

Students will be able to identify different tools for observation and to determine the best visualization device for specific questions.

KEY TOPICS

- Microscopy
- SEM
- CT scan

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
20 minutes	**Review: Microbiodiversity**	Review Discussion questions from pond water unit. Instructor should ask each group to summarize its findings.
30 minutes	**Lecture: How Do Scientists Visualize Samples** **Activity**	Introduction to scientific tools used for observing biodiversity.
30 minutes	**Visit of the Imaging Facility**	Tour of the SEM, confocal microscope and CT scanner. Students should take notes and think of a question to can research for homework and share with the class.
40 minutes	**Visit of the temporary exhibition "Picturing Science"**	Alternative: go over the equipment housed in the imaging facility (http://www.amnh.org/our-research/microscopy-and-imaging-facility/instruments) and its functions, or arrange for tour of local imaging equipment. Complete exercise. Students will leave from the "Picturing Science" exhibit.

Session Seven: Tools for Studying Biodiversity (continued)

MATERIALS

- Picturing Science worksheet
- If not using exhibit, images to use in activity

PREPARATION

Organize a tour of the imaging facility.

HALLS

Temporary Exhibition "Picturing Science" and the Imaging Facility on the 5th Floor

AUDIO-VISUAL NEEDS

Computer and projector

HOMEWORK

Research a question from the tour of the imaging facility.

Session Seven: Tools for Studying Biodiversity: ACTIVITY

Picturing Science

OVERVIEW

Students will use actual images to learn about observation techniques and tools.

TIME FRAME

40 minutes

MATERIALS

Worksheet and temporary hall 'Picturing Science'

Alternative: If there is no access to the exhibit, instructors can find images generated by various machines and let students fill out the worksheet on this basis.

PROCEDURE

1. Have students work in pairs, walk around the exhibit or photos on tables, and fill in the worksheet.
2. Have students answer the question, Why are there many techniques to observe biodiversity?
3. Back in the classroom, or at the beginning of the next period, have each group describe one technique to the class.

WORKSHEET

Scientific Tools to Observe Biodiversity

Session Seven: Tools for Studying Biodiversity: WORKSHEET

Scientific Tools to Observe Biodiversity

For each listed title, observe the image in the "Picturing Science" exhibition and fill out the table.

	Before reading the legend, write down what you think the image represents.	What organism is it?	How did you observe it? Summarize the way that technique works.	What structure is represented in the image(s)?	Why do you think this technique was used?	What did scientists learn from the image?
TRUE BUGS						
RODENT'S TEETH						
PLANT BUG						
EXTINCT PRIMATE'S SKULL						
ANCIENT ANT						
YELLOW JACKET, WASP & HORNET						
ARMADILLO LIZARD						
ANCIENT MOLLUSK JAW						
CICHLID, PONY FISH AND MACKERELL						
FLUORESCENT CORALS						
BACTERIA IN LEECHES						

Why are there many techniques to observe biodiversity?

Session Eight: Invertebrates

LEARNING OBJECTIVES

Students will be able to identify the main phyla of invertebrates, perform comparative analysis of several invertebrates, recognize the basic structure of two types of mollusk, recognize the basic structure of a cnidarian, recognize the basic structure of an annelid, and recognize the basic structure of a cephalopod.

KEY TOPICS

- Metazoa
- Porifera
- Cnideria and Ctenophora
- Deutorostomia
- Echinodermata
- Platyhelminthes
- Cephalopoda

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
10 minutes	**Review: Picturing Science**	Instructors go over Picturing Science activity. They should lead a group discussion about what question was being asked and why different methods were used. Ask students to match new questions with specific methods.
45 minutes	**Lecture: Invertebrates**	Introduction to the invertebrates, their place on the tree of life, the major phyla, and how they're defined.
60 minutes	**Activity: Dissection and Comparative Anatomy**	Recognize the basic structure and organization of a cnidarian, an annelid, two types of mollusk, and a cephalopod. Compare and contrast the anatomy of passive versus active organisms.
15 minutes	**Wrap Up**	Students can ask questions, etc. Any unfinished discussion questions should be completed as homework.

Session Eight: Invertebrates (continued)

MATERIALS

- Dissection kit
- Mollusks, cniderian, annelid, cephalopoda
- Worksheet for dissection (Invertebrate Biology Lab.pdf)

AUDIO-VISUAL NEEDS

Computer and projector

Session Eight: Invertebrates: ACTIVITY

Dissection and Comparative Anatomy

OVERVIEW

This activity will teach students to recognize the basic structure and organization of the sample organisms — a cnidarian, an annelid, two types of mollusk, and a cephalopod. They will compare and contrast the anatomy of passive versus active organisms.

TIME FRAME

60 minutes

MATERIALS

Specimens (1 type per student group), dissection kit and tray, gloves.

Alternative: If there is no access to the exhibit, instructors can find images generated by various machines and let students fill out the worksheet on this basis.

PROCEDURE

1. Distribute the handout and walk through the procedures.
2. Distribute trays with all specimens and dissection material.
3. Have students complete the activity, working in their groups and focusing on the differences between sedentary animals and active predators.

Session Nine: Entomology: Introduction to Insect Anatomy

LEARNING OBJECTIVES

Students will be able to place insects in the tree of life, know the general features of major clades of insects, identify orders of insects based on distinguishing characteristics, use an identification key, manipulate pinned insects, and dissect a grasshopper and identify its major parts.

KEY TOPICS

- Anthropoda
- Hexapoda
- Insect Anatomy

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
15 minutes	**Review: Picturing Science**	Instructors divide students into groups of three or four and Picturing Science Activity. Instructors should lead a group discussion about what question was being asked and why different methods were used. Ask students to match new questions with specific methods.
30 minutes	**Lecture: Insects and the Tree of Life**	Introduction to the orders of insects and their morphological characteristics. Introduction to the Arthropods and their defining characters.
20 minutes	**Activity: Dissection and Comparative Anatomy**	Instructors should pass around pinned insects from the teaching collections and the handout for identifying insects. Each group should have some identified insects and some unidentified ones. Students should use a hand lens to identify insects to the order level. Instructors should check on student answers.
60 minutes	**Wrap Up**	Grasshopper dissection. Each group will get a dissecting tray with a grasshopper and dissection tools. Students should observe the grasshopper's external anatomy , label morphological structures on the drawings provided (head and body), and complete the handout.

Session Nine: Entomology: Introduction to Insect Anatomy (continued)

MATERIALS

- Dissection kit
- Grasshoppers
- Handouts (Session9-Entomology-handout.doc)
- Insect collections
- Instructions for grasshopper dissection

AUDIO-VISUAL NEEDS

Projector

HOMEWORK

Complete questions from grasshopper activity

Session Nine: Entomology: Introduction to Insect Anatomy: ACTIVITY

Using a Collection to Identify the Main Orders of Insects

OVERVIEW

Students look into pinned insects collection and use an identification key to identify common insects to the level of Order.

TIME FRAME

20 minutes

MATERIALS

A collection of a few pinned insects, dissecting microscope, and identification key to the order of insects (online key: http://www.sci.sdsu.edu/classes/bio462/easykey.html)

PROCEDURE

1. Distribute a box of pinned insects to each group. Explain how to take out specimens out of the box and place them on foam for observation.
2. Ask them to write down a pre-identification of each specimen on the handout
3. Give them access to the identification key and identify the specimens.
4. Have them fill out the handout, which includes a rough drawing and list of characters

Session Nine: Entomology: Introduction to Insect Anatomy: ACTIVITY

Grasshopper Dissection

OVERVIEW

Students observe a grasshopper's external anatomy of and use it as a model organism to understand the general morphology of insects. They will label anatomical structures and place the grasshopper on the tree of life.

TIME FRAME

60 minutes

MATERIALS

Grasshopper (1 per student or per pair of students, depending on availability), dissection kit and tray, gloves.

PROCEDURE

1. Distribute the handout. Have them work on the classification of the grasshopper.
2. Distribute a grasshopper and dissection material.
3. Have groups complete the handout.

WORKSHEET

Entomology - The Major Clades of Insects

Session Nine: Entomology: Introduction to Insect Anatomy: WORKSHEET

Entomology - The Major Clades of Insects

Use pinned specimens and a dissecting microscope to identify main groups of insects.

1. Choose five specimens. Have a first look at each specimen and write down what the name of each might be. If necessary, guess. If you really have no idea, write "I don't know".

   I think:

   Specimen #1 is a _____ Specimen #2 is a _____

   Specimen #3 is a _____ Specimen #4 is a _____

   Specimen #5 is a _____

2. Use this identification key of different orders of insects to identify your specimens.

3. Fill out the following:

SPECIMEN	ORDER	COMMON NAME	CHARACTERISTIC FEATURE
#1			
#2			
#3			
#4			
#5			

Session Ten: Vertebrates-Ichthyology

LEARNING OBJECTIVES

Students will be able to place fishes in the tree of life, know the general features of major classes of fishes, use an identification key, recognize the basic structure and organization of a chondrichthyian and an osteichthyian, compare and contrast the anatomy of these two taxa.

KEY TOPICS

- Chondrichthyian
- Osteichthyian
- Chimaera
- Sharks
- Rays
- Cartilaginous skeleton

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
45 minutes	**Review: Vertebrates - Ichthyology**	Introduction to vertebrates, starting with fishes: where they fit in the tree of life, major phyla, and how they're defined.
60 minutes	**Activity: Dissection and Comparative Anatomy**	Basic structure and organization of a chondrichthyian and an osteichthyian. Compare and contrast cartilaginous and bony skeletons
15 minutes	**Wrap Up**	Students express questions, comments, criticisms, and concerns. Any unanswered discussion questions should be completed as homework.

Session Ten: Vertebrates-Ichthyology (continued)

MATERIALS

- Dissection kit
- Chondrichthyian and an osteichthyian
- Worksheet for dissection (Ichthyology Lab.docx)

AUDIO-VISUAL NEEDS

Computer and projector

Session Ten: Vertebrates-Ichthyology: ACTIVITY

Dissection and Comparative Anatomy

OVERVIEW

Students recognize the basic structure and organization of a chondrichthyian and an osteichthyian, and compare and contrast the anatomy of cartilaginous and bony fishes.

TIME FRAME

60 minutes

MATERIALS

Specimens (1 type per student group), dissection kit and tray, gloves.

PROCEDURE

1. Divide students into small groups, distribute the handout and walk through the procedure.
2. Distribute trays with all specimens and dissection material,
3. Have groups review the handout and answer discussion questions about the differences between bony fishes and cartilaginous fishes. (Finish as homework if necessary.)

Session Ten: Vertebrates-Ichthyology: LAB

Ichthyology Lab

OBJECTIVES

Recognize the basic structure and organization of a chondrichthyian and an osteichthyian. Compare and contrast the anatomy of these two taxa.

Class Chondrichthyes

- Chimaera, Sharks and Rays
- Cartilaginous skeleton except for calcified jaws
- Males have two intromittent organs (claspers) associated with their pelvic fins

EXERCISE 1: SPINY DOGFISH (SQUALUS ACANTHIAS) ANATOMY

1. Sketch the organism and identify the following regions or structures:
    - Dorsal fin
    - Pelvic fin (w/ claspers if present)
    - Pectoral fin
    - Gill openings
    - Heterocercal caudal fin
    - Spiracle
2. Use your scissors to cut along the length of the body (from anus to jaws) to expose the viscera. Sketch the internal anatomy, identifying the following structures:
    - Spiracle
    - Stomach
    - Spiral valve intestine (cut an inch or two along its length to see the "spiral valve")
    - Gonads
    - Kidneys
    - Rectal Gland

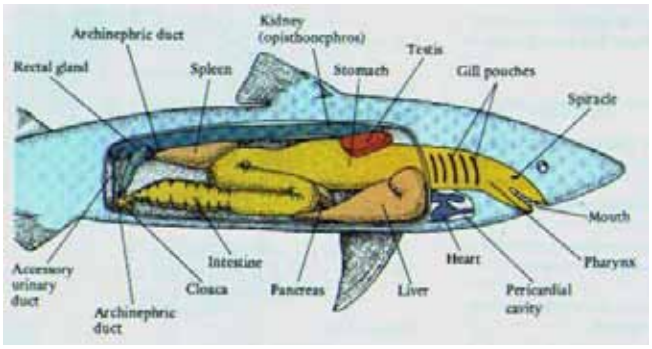

Fig. 1 General anatomy of a shark

LAB: Ichthyology Lab (continued)

Class Osteichthyes

- Bony fishes: Everything else, including tetrapods
- About 25,000 species

EXERCISE 2: BONY FISH ANATOMY

Use the diagram below of a yellow perch as a guide. Your fish will be DIFFERENT.

1. Sketch the whole fish and identify:
    - Dorsal/Anal fins
    - Pelvic/Pectoral fins
    - Gill opening (Operculum)
2. Use your scissors to cut along the length of the body (from anus to throat) to expose the viscera. Sketch the internal anatomy and identifying the following structures:
    - Liver
    - Gas bladder (may be intact or cut)
    - Gill arches with filaments
    - Stomach
    - Intestine
    - Kidney
    - Gonads
3. Go around the room and take a good look at the other fishes.

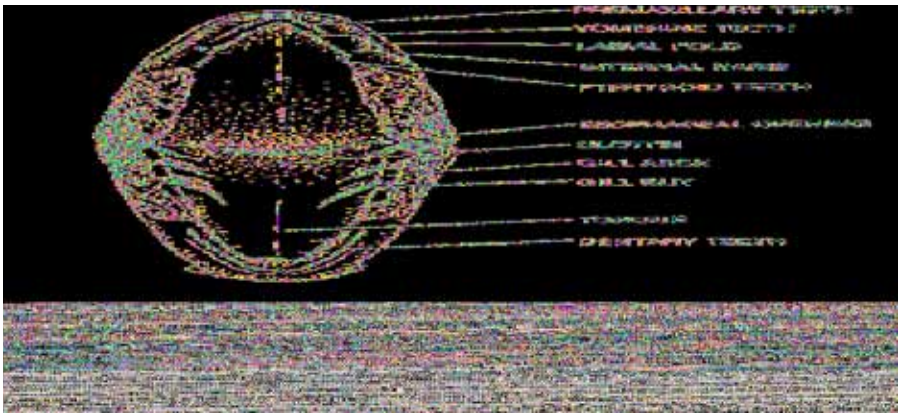

Fig. 2 Anatomy of a Yellow Perch

LAB: Ichthyology Lab (continued)

QUESTIONS

1. Without a gas bladder, how do sharks stay buoyant?

2. Why do you think some fish are laterally compressed and some rounder in shape?

3. What might be the advantage of a bony skeleton?

Session Eleven: Vertebrates-Tetrapods

LEARNING OBJECTIVES

Students will be able to place the tetrapods in the tree of life, know the general features of major classes of tetrapods, use an identification key, recognize the basic structure and organization of an amphibian, a mammalian, and an avian specimen, and compare and contrast the external and internal anatomy of these taxa.

KEY TOPICS

- Amphibian
- Mammal
- Avian

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
45 minutes	**Review: Vertebrates - Tetrapods**	Introduction to vertebrates, starting with fishes: where they fit in the tree of life, major phyla, and how they're defined.
60 minutes	**Activity: Dissection and Comparative Anatomy**	Recognize the basic structure and organization of an amphibian, a mammalian, and an avian specimen. Compare and contrast external and internal anatomy.
15 minutes	**Wrap Up**	Students express questions, comments, criticisms, and concerns. Any unanswered discussion questions should be completed as homework.

MATERIALS

- Dissection kit
- An amphibian, a mammalian, and an avian specimen
- Worksheet for dissection (Tetrapod Lab.docx)

AUDIO-VISUAL NEEDS

Computer and projector

Session Eleven: Vertebrates-Tetrapods: ACTIVITY

Dissection and Comparative Anatomy

OVERVIEW

Students learn to recognize the basic structure and organization of an amphibian, a mammalian, and an avian specimen, and compare and contrast external and internal anatomy.

TIME FRAME

60 minutes

MATERIALS

Specimens (1 type per student group), dissection kit and tray, gloves

PROCEDURE

1. Divide students into small groups, distribute the handout and walk through the procedure.
2. Distribute trays with all specimens and dissection material.
3. Have groups review the handout and answer discussion questions about the differences between bony fishes and cartilaginous fishes. (Finish as homework if necessary.)

Session Eleven: Vertebrates-Tetrapods: LAB

TETRAPOD Lab

OBJECTIVES

Recognize the basic structure and organization of an amphibian, a mammalian and an avian specimen. Compare and contrast their external and internal anatomy.

Class Amphibia

- **Chimaera, Sharks and Rays**
- **Cartilaginous skeleton except for calcified jaws**
- **Males have two intromittent organs (claspers) associated with their pelvic fins**

EXERCISE 1: MUDPUPPY (NECTURUS SP.) ANATOMY [FIG. 1]

1. **Open the mouth and make two cuts in each corner to allow you to view deeper into the buccal cavity. Identify the following structures:**
   - **Teeth (dentary, premaxillary, vomerine and pterygoid (Does this sound like the fish anatomy we discussed last class?)**
   - **Gill arch and gill slit (Again, does this sound like the fish anatomy discussed last class?)**
2. **Use your scissors to cut along the length of the body (from anus to jaws, using scissors to cut through the sternum) to expose the viscera. Sketch the internal anatomy, identifying the following structures:**
   - **Stomach**
   - **Liver**
   - **Lung**
   - **Gonad**
   - **Kidney**
   - **Cloaca (Follow this opening with your probe, and observe how the genitourinary and alimentary (gastrointestinal) tracts both terminate here.)**

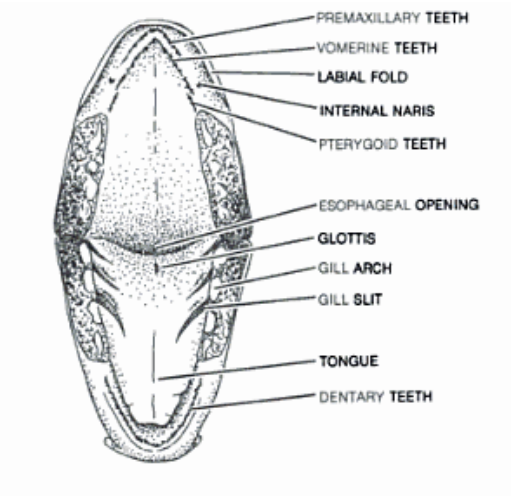

Fig. 1

LAB: Tetrapod Lab (continued)

Class Aves

- Have feathers, respire using lungs
- Lay amniotic eggs with a shell

EXERCISE 2: PIGEON (COLUMBIA NIVIA) ANATOMY [FIG. 2]

Use the diagram below of a yellow perch as a guide. Your fish will be DIFFERENT.

1. Examine, sketch and identify all the different types of feathers on a pigeon.
2. Sketch and identify the major components of a contour feather (from the lecture slides).
3. Examine the beak and note any teeth or tooth like structures.
4. Use your scissors to cut along the length of the body (from anus to neck). Peel back the skin and then use your scalpel to carve away the pectoralis muscles. You'll see the large sternal keel. Use scissors to cut the ribs on both sides, and remove the ribcage and sternal keel to expose the internal organs.
    - Liver
    - Stomach
    - Gizzard
    - Lung
    - If female: uterus with ovaries; if male: penis and testes
    - Kidney
    - Cloaca

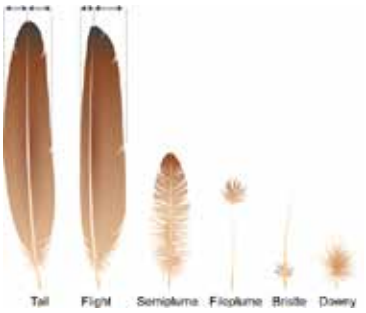

Fig. 2

LAB: Tetrapod Lab (continued)

Class Mammalia

- Have hair, mammary glands respire using lungs
- Are viviparous (give live birth)

EXERCISE 3: MINK (NEOVISON VISON) ANATOMY [FIG. 3]

1. Use your scissors to cut along the length of the body (from anus to neck). Peel back the skin and then use your scalpel to carve away the pectoralis muscles. You'll see the large sternal keel. Use scissors to cut the ribs on both sides, and remove the ribcage and sternal keel to expose the internal organs.
    - Teeth (incisors, canines, premolars and molars (largest is the carnassial))
    - Maxilla and mandible
    - Tongue
2. Use your scissors to cut along the length of the body (from anus to neck). Peel back the skin and then use your scalpel to carve away the pectoralis muscles. You'll see the large sternal keel. Use scissors to cut the ribs on both sides, and remove the ribcage and sternal keel to expose the internal organs.
    - Liver
    - Stomach
    - Lung
    - If female: uterus with ovaries; if male: penis and testes
    - Kidney
    - Anus

LAB: Tetrapod Lab (continued)

QUESTIONS

1. What do you think a cloaca is? Do all three taxa have one? If not, why not?

2. What do you think the function of carnassial teeth might be? Which other mammal groups might you expect to have this type of tooth?

3. How do the jaws of all three taxa differ? Which of the three jaw types do you think is probably most ancestral? Why?

4. Name three specializations birds have evolved for powered flight. (You may need to ask your instructor to suggest one.) Compare and contrast these adaptations to the (presumably homologous) structures found in the other two tetrapods.

Session Twelve: Reconstructing the Tree of Life for Vertebrata

LEARNING OBJECTIVES

Students will be able to reconstruct the tree of vertebrates using the Halls of Vertebrate Origins, and identify synapomorphies for major clades.

KEY TOPICS

- Diversity of Vertebrata
- Synapomorphies of major clades
- Fossils and living groups

CLASS OUTLINE

TIME	TOPIC	DESCRIPTION
120 minutes	**Activity: Reconstruct the Tree of Life**	This activity acts as a final presentation and reviews major topics from the course.

MATERIALS

- Worksheet
- Pencils & paper
- If not using halls, computer access for students

HALLS USED

Hall of Vertebrate Origins (4th Floor)

HOMEWORK

Finish the tree at home and email to instructors.

Session Twelve: Reconsructing the Tree of Life: ACTIVITY

Reconstructing the Vertebrata Tree of Life

OVERVIEW

Using the Hall of Vertebrate Origins, draw a tree that depicts the relationships for the major vertebrate taxa. If you don't have access to halls, use the alternate activity worksheet. It requires internet access.

TIME FRAME

120 minutes

MATERIALS

Paper and pencils

PROCEDURE

If using halls:

1. Distribute the handout and walk through the procedure with students.
2. Take students to the vertebrate evolution halls.
3. Have them answer discussion questions. (Complete for homework if necessary.)

HANDOUT QUESTIONS

Distribute the handout and walk through the procedure with students.

1. Draw one tree that depicts the relationships of all the following taxa (i.e., all taxa on one tree):
   - Hall of Vertebrate Origins: Dunkleosteus, Carcharodon, Xiphactinus, Latimeria, Buettneria, Stupendemys, Thalassomedon, Tylosaurus, Pteranodon
   - Hall of Saurischian Dinosaurs: Apatosaurus, Tyrannosaurus, Archaeopteryx
   - Hall of Ornithischian Dinosaurs: Stegosaurus, Corythosaurus
   - Hall of Primitive Mammals: Dimetrodon, Diprotodon, Glyptotherium
   - Milstein Hall of Advanced Mammals: Vulpavus, Homo, Amphicyon, Notharctus, Mesophippus, Brontops, Andrewsarchus, Platybelodon, Mammuthus
2. Provide synapomorphies for all clades on your tree (as many as you can find).

ACTIVITY: Reconsructing the Vertebrata Tree of Life (continued)

If not using halls:

1. Distribute the handout and walk through the procedure with students.
2. Take students to the vertebrate evolution halls.
3. Have them answer discussion questions. (Complete for homework if necessary.)