

**Biology Inquiry and Outreach with Boston University Graduate Students (BIOBUGS)  
presents: Comparative Vertebrate Anatomy**

In the same way that a dead body can provide forensic detectives with the clues to solve a murder case, the bodies of animals can tell us a lot about their ecology and evolution. In this lab we will study the internal anatomy of the five classes of the vertebrates (fish, amphibian, reptile, bird, and mammal) through hands-on examination of dissected whole specimens as well as prepared skeletons and skins. We will ask students to formulate hypotheses about the ecology of each dissected species based on their observations of the similarities and differences between each specimen. Students will also learn how to use their morphological observations to construct a phylogenetic hypothesis of the evolutionary history of each vertebrate class.

Massachusetts Educational Standards addressed by this lab:

Scientific Inquiry Skill Standards:

SIS1 – Make observations, raise questions, formulate hypotheses

SIS3 – Analyze and interpret results of scientific investigations

Biology Standards:

4. Anatomy and Physiology

5. Evolution and Biodiversity

6. Ecology

**Lesson Topic:** Comparative Vertebrate Anatomy

**Materials (for 24 students)**

We will need twice this much for two sections.

Powerpoint projector

Computer

Chalk, Whiteboard Pens, or Butcher Paper and Pens

Student worksheet

Disposal for dissections

Magnifying Glasses

Rulers

24 pairs of gloves

24 pairs of protective glasses

**Part 1: Skeletal Anatomy (Bio Museum)**

Station 1: Skulls from Coyote, Bear and Deer. No labels.

Station 2: Skulls from Bat, Shrew, and two dissection microscopes with light.

Station 3: Skeletons of Pigeon, Bat

Station 4: Skeletons of Salamander, Pigeon, Frog

Station 5: Skeletons of Turtle, Perch

Station 6: Skeleton of Cat

**Part 2: Internal Anatomy (Carolina Biological Supplies)**

Disposable Gloves!

Dissecting tools for instructors only (1 of each species)

Magnifying glasses

Station 1: Cat (to be dissected in demo)

Station 2: Turtle (pre-dissected)

Station 3: Pigeon (pre-dissected)

Station 4: Salamander (pre-dissected)

Station 5: Perch (pre-dissected)

Station 6: Dogfish (pre-dissected)

## **Part 1: Skeletal Anatomy: Roll Them Bones (1 Hour)**

**Introductory Lecture:** This lecture will be important for setting the tone of the lab, as well as some sort of theme. Personally I favor a CSI/Cold Case theme, as this will engage many of the students. We can use this theme to introduce the idea of dissecting bodies for clues to the ecology and life history of the animal, and especially learning by comparing anatomy of many animals. We can also use this theme to emphasize the need for students to act like professional investigators, not bothered by smells or gross (in both senses of the word) anatomy. We will need to introduce the vertebrates, but without much detail – possibly just as the group of animals united by having vertebrae. We will also introduce an outline of the lab, so the students know what to expect.

The students will be broken into 6 groups of 4 and rotate through six stations where they will explore the skeletal anatomy of various vertebrates and asked questions regarding their natural history and ecology. This section will be inquiry based in that the questions will be open ended, and we will not provide any answers until the end, when we work it out as a group. The students will have ~5 minutes at each station. We should probably get one volunteer to be the recorder for the group (maybe one who is good at drawing, or doesn't want to touch dead animals).

### **Station 1: Skulls Tell Stories 1**

In their handout, students will be provided with a drawing of a mammalian skull that is labeled with the following anatomical characteristics: the orbit, the nasal passage, the auditory bullae, and the major groups of teeth: incisors, canines, premolars and molars. They will be presented with 3 unlabelled skulls from an herbivore, a carnivore and an omnivore and asked to fill out a worksheet comparing the above characteristics between skulls. They will be asked several questions regarding their inferences from these characteristics about the animal's trophic level and way of life.

### **Station 2: Skulls Tell Stories 2**

Students will continue their exploration of skulls, this time with the tiny skulls from a shrew and a bat that they will be able to observe through dissecting microscopes. As these skulls will be less familiar to the students (and smaller), the inference of lifestyle will be more challenging.

### **Station 3: First in Flight: Bats vs. Birds**

Students will be provided with a labeled diagram of the bones in a human arm and asked to compare this to the bones in a pigeon wing and a bat wing and look for similarities and differences in which bones support the main structure of the wing.

Students should also note the following characters in the pigeon:

Presence/absence of calcified bone

Presence/absence of vertebrae

Presence/absence dorsal process on vertebrae

Presence/absence of 4 walking limbs

Presence/absence of beak

Presence/absence of shell

#### **Station 4: Fusion Power**

Students will be asked to compare the skeletons of a salamander, a frog and a pigeon. They will be told that the well-developed and flat urostyle in the frog is a result of the fusion of many bones in the pelvic girdle (the hip bones), and the well developed and flat keel and furcula (wishbone) of the pigeon come from the fusion of many bones in the pectoral girdle (the shoulder and chest bones). They will be able to see that these bones are not fused in the salamander. They will be asked to think of possible reasons why both the urostyle and keel are so flat (muscle attachment).

Students should also note the following characters in the salamander:

- Presence/absence of calcified bone
- Presence/absence of vertebrae
- Presence/absence dorsal process on vertebrae
- Presence/absence of 4 walking limbs
- Presence/absence of beak
- Presence/absence of shell

#### **Station 5: Pet Cemetery: Turtle and Fish**

Students will have a chance to examine the skeletons of a turtle and a fish to gather further characters for their phylogeny. Characters they should get at this station for each skeleton:

- Presence/absence of calcified bone
- Presence/absence of vertebrae
- Presence/absence dorsal process on vertebrae
- Presence/absence of 4 walking limbs
- Presence/absence of beak
- Presence/absence of shell

#### **Station 6: Cat Skeleton**

Students will have a chance to examine the skeletons of a cat to gather further characters for their phylogeny. Characters they should get at this station for each skeleton:

- Presence/absence of calcified bone
- Presence/absence of vertebrae
- Presence/absence dorsal process on vertebrae
- Presence/absence of 4 walking limbs
- Presence/absence of beak
- Presence/absence of shell

Closing Discussion:

We will need to have everyone sit down and go through the worksheet, and try to get the group to come up with some answers through guided discussion, either using the board, or a projector and computer. Important concepts to teach here are how skull adaptations reflect trophic level and lifestyle in mammals (from Stations 1 and 2), and the concept of homology and the difference between homology and homoplasy (Stations 3 and 4). Discussion of the phylogeny characters can be held off until part 3.

## **Part 2: Internal Anatomy (1.5 hours)**

**Introductory Lecture and Dissection Demo:** See Comparative Anatomy Instructor for proper cat dissection and lecture. Here we can unite the concepts of homology and adaptation and have the students consider how homologous structures differ between animals, based on their habitat and life history. This should pretty much lead into the demo of the cat dissection, during which the instructor should refresh the students on the basic functions of the homologous structures listed below.

The students should keep track of the relative size and shape of the following homologous structures: Heart, Lungs/Swim Bladder, Large Intestine, Kidney, Liver, Skin Covering. Each member of each group should choose between these structures as the one that they want to specialize in, and be in charge of drawing this structure in each of the animals as the group moves around the stations.

Activities at each station will be the same. Students should make observations on each of the structures above in their chart. They should then draw their assigned structure in space provided on the worksheet. Anyone working on skin should be encouraged to draw a single unit of the skin covering at magnification. Finally, they should collect the following characters:

Relative size of large intestine  
Presence/Absence of Diaphragm  
Skin Covering

Station 1: Cat (8 minutes)

Station 2: Turtle (8 minutes)

Station 3: Pigeon (8 minutes)

Station 4: Salamander (8 minutes)

Station 5: Perch (8 minutes)

Station 6: Dogfish (8 minutes)

Closing Discussion:

Each group should briefly (in a minute or less) present their findings about the trait they investigated. They should point out trends or major differences that they noticed. We can then have a brief guided discussion about why differences in these traits might help each organisms adapt to their habitat.

**Part 3: Phylogeny (30 minutes)**

**Introductory Lecture:** This lecture will cover only the very basics of phylogenetics. We will cover how a phylogeny is related to a family tree, and the following terminology: common ancestor, clade, character. We will then construct a hypothesis for the vertebrate phylogeny using the characters that the students have created. This will be an interactive process, with the leader prompting the students for how to proceed. The tree will first be drawn on the blackboard either by a student volunteer or a graduate student. The powerpoint slides will follow along as the students come to the “correct” answer.

	1. Vertebrae	2. Calcified bone	3. 4 limbs	4. Egg with Amnion	5. Pronounced Large Intestine	6. Skin Covering	7. Pronounced Dorsal Process on vertebrae	8. Egg with mineralized shell	9. Lower Jaw Bones fused, without teeth, into	10. Keeled Breastbone	11. Diaphragm	12. Thoracic vertebrae fused into shell
<b>Shark</b>	1	0	0	0	0	1	0	0	0	0		0
<b>Perch</b>	1	1	0	0	0	2	0	0	0	0	0	0
<b>Salamander</b>	1	1	1	0	0	3	0	0	0	0	0	0
<b>Turtle</b>	1	1	1	1	1	4	0	1	1	0	0	1
<b>Pigeon</b>	1	1	1	1	1	5	0	1	1	1	0	0
<b>Cat</b>	1	1	1	1	1	6	1	0	0	0	1	0

