Mammal Skulls, Teeth, Bones, Dichotomous Keys\*, and Homologies

\*Information taken from the Animal Diversity Web (<https://animaldiversity.org/accounts/Mammalia/>) and Mammalogy Techniques Lab Manual by Dr. James Ryan.

There are more than 5,000 living species of mammals. Because many species (especially species of small mammals) appear similar to the untrained eye, scientists have developed dichotomous keys to facilitate identification of species. Dichotomous keys are pairs of statements that allow the user to easily identify an unknown organism. The keys are arranged in “couplets” consisting of two statements that ask the user to make a choice about the presence, absence, or aspect of a particular characteristic of their unknown organism. That choice leads the user to a new couplet in the key, and the process repeats until a couplet choice leads to the name of the organism (or the group to which it belongs).

Most dichotomous keys use scientific terminology to describe features. Thus, it is often important to familiarize yourself with basic anatomical terminology before attempting to use a key. **Mammal skulls and teeth are often used in keys to identify species.** However, mammal skulls are complex structures made up of numerous bones, processes, holes, and teeth (usually). Each feature is important and has been shaped by natural selection. For example, the diverse feeding habits of mammals are reflected in their teeth and jaw morphology. Teeth may be specialized for grasping, crushing, or grinding; the position and structure of the teeth often provide valuable clues to the animal’s diet. Below are figures that will help you learn to recognize identifying features of mammal skull, teeth, and bones, and these will help you work through dichotomous keys and address a variety of questions.

Useful terms:

Diphyodonty – 2 sets of teeth (milk teeth and adult teeth)

Lingual – toward the tongue

Labial – toward the lip or cheek

Occlusal Pattern – way teeth mesh together

Diastema – Space between teeth

Dentary – bone of the lower jaw

Foramen (or foramina) = hole in bone (nerve or blood vessel passes through this hole)

Fenestra = many small holes in a region of bone

Fossa = depression in bone (usually site of muscle attachment)

Process = a boney projection

Condyle = a process on one bone that articulates with another bone

Bulla (bullae) = bone(s) that cover the middle ear ossicles

Postorbital bar = bone behind the orbit

Anterior = towards the nose

Posterior = towards the back of the skull

Ventral = underside

Dorsal = topside

Canal = tunnel-like hole in bone (oftentimes 2 foramen connected)

Meatus = the opening into a canal

**Examine the labeled skulls on the powerpoint and get familiar with the highlighted bones**

Practice labeling your own bones here:





**Teeth!**

Mammals have four types of teeth: Incisors (I), Canines (C), Premolars (PM), and Molars (M). -Teeth restricted to 3 bones: premaxilla, maxilla, and dentary. Premolars and Molars indicate diet and age (wear on the tooth); molars only come in as adults. Premolars and molars combined are often referred to as cheekteeth.

Tooth Formulas:

Upper Incisor/Lower Incisor, Upper Canine/Lower Canine, Upper Premolar/Lower Premolar, Upper Molar/Lower Molar **X 2** (both halves of the skull)

Marsupial mammals: 5/4, 1/1, 3/3, 4/4 = 50 maximum

Placental mammals: 3/3, 1/1, 4/4, 3/3 = 44 maximum

Tooth formulas shown above is for ½ of the jaw. Be sure to double everything to get the final number of teeth after the “=” sign! Note, sometimes premolars and molars are hard to tell apart.



Figure 4. Major tooth types on a mammal skull. This specimen has **heterodont** dentition (more than one kind of tooth). This is in contrast to **homodont** dentition (only one type of tooth; all the teeth look the same).

For your assignment (see below), you will need to use a dichotomous key to identify specimens to orders. Here are some videos covering how to use a dichotomous key:

<https://www.youtube.com/watch?v=M51AKJqx-7s> AND <https://www.youtube.com/watch?v=peMiaDhw9sc>

**Dichotomous Key**

1.a. Incisors 1/1 or 2/1 (second upper incisor peglike and set directly behind the first);

broad diastema between incisors and cheekteeth; first upper incisor enlarged,

evergrowing, modified for gnawing ………………………………………………..……………..…go to 2

1.b. Incisors variable (never 1/1 or 2/1) to absent; if incisors present both above and

below, no diastema, or only a modest diastema, in toothrow; first upper incisor,

if present, usually not noticeably enlarged, not evergrowing, not modified for gnawing…………....go to 3

2.a. Incisors 2/1; maxillary fenestration(s) present………………..…………..…**Order** **LAGOMORPHA**

2.b. Incisors 1/1; no maxillary fenestrations…………………………………...………**Order** **RODENTIA**

3.a. Incisors lacking; cheekteeth peglike, lacking enamel…………………..….……**Order CINGULATA**

3.b. Incisors present in at least lower jaw; cheek teeth not peglike,

composed partly of enamel……………………………………………………………………..….…go to 4

4.a. Incisors 5/4; angular process of dentary distinctly inflected…………...Order **DIDELPHIMORPHIA**

4.b. Incisors never more than 3/3; angular process of dentary not inflected……………..………..…go to 5

5.a. Upper incisors sometimes absent; upper canine absent or, if present, separated from

cheekteeth by modest diastema; postorbital bar present…….....…………**Order CETARTIODACTYLA**

 **(terrestrial forms)**

5.b. Upper incisors present; upper canine present and not separated from cheekteeth

by diastema; postorbital bar absent…………………………………………….……………..………go to 6

6.a. Greatest length of skull less than 45 mm; Molars 3/3, last upper molar never

dumbbell-shaped (careful, molars and premolars can look alike!); cheek teeth often

> 4/4; number of incisors variable………………………………………….………………..…….…go to 7

6.b. Greatest length of skull usually more than 45 mm (if less, then last upper molar is dumbbell shaped); upper incisors always 3 in number; Molars rarely 3/3 (careful, molars and premolars can look alike!); cheek teeth often 3/3 or 4/4……………………………………………………….…**Order CARNIVORA**

7.a. Canine poorly to moderately developed, never largest tooth in anterior part

of toothrow; dorsal profile of skull flattened; braincase not much higher than rostrum…………………………………………………..................……………**Order** **EULIPOTYPHLA**

7.b. Canine well developed, largest tooth in anterior part of toothrow; total number

of teeth never more than 38; dorsal profile of skull not flattened, braincase noticeably

higher than rostrum (there are a few exceptions)………….……...……………..…**Order CHIROPTERA**

**Lab Assignment – Part 1 (5 pts)**

1. Use the skull and teeth information above and the dichotomous key below to identify the specimens in the powerpoint to order.

Specimen A: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Eulipotyphla (1 pt)

Specimen B: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Carnivora (1 pt)

Specimen C: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Chiroptera (1 pt)

Specimen D: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Cetartiodactyla (1 pt)

Specimen E: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Lagomorpha (1 pt)

**Homologies Among Bones**

The skeletal structures of forelimbs in various vertebrate animals showing the homologies among bones. Comparative anatomists realized that although these vertebrates evolved in different directions, with changes in size, shape, and function, they all used common bone elements, as well as homologous nerve systems, blood circulatory systems, and other organ systems, indicating a common vertebrate ancester.

As Darwin noted, “What can be more curious than that the hand of man formed for grasping, that of a mole, for digging, the leg of a horse, the paddle of a porpoise and the wing of a bat, should all be constructed on the same pattern and should include similar bones and in the same relative positions?” Thus, in contrast to teleological explanations that emphasize design for a particular function, the vertebrate forelimb uses a common underlying ancestral structure for different functions.

Recall definitions of homology and analogy here: <https://evolution.berkeley.edu/evolibrary/article/evo_09>

And here:

<https://evolution.berkeley.edu/evolibrary/article/0_0_0/homology_01> (scroll through and read all of the pages by clicking the “next” button at the bottom of each page)

And here:

<https://evolution.berkeley.edu/evolibrary/article/0_0_0/similarity_ms_01> (scroll through and read all of the pages by clicking the “next” button at the bottom of each page)

**Lab Assignment – Part 2 (7 pts)**

Using the links above (especially the last link), answer the following questions about homology and analogy:

1. Explain the difference in homology and analogy. (1 pt)

Homology – trait shared between different organisms based on evolutionary history/common ancestry. Trait is inherited.

Analogy – trait shared between different organisms not based on evolutionary history/common ancestry. Convergent evolution; trait is not inherited.

2. List the similarities that tetrapod limbs share: (1 pt)

A. They are built from the same individual bones

B. They are spin-offs of the same basic bone layout (one long bone, humerus, attached to tow other long bones, radius and ulna) with a branching series of smaller bones (carpals, metacarpals, phalanges) on the end

3. Why do whales, lizards, humans, and birds have the same basic limb structure? (1 pt)

They inherited it from a common ancestor

4. What does an evolutionary tree show? (1 pt)

shows relationships over time

5. What are homologous structures? List examples of homologous structures found in nature. (1 pt)

Structures inherited from a common ancestor

Leaves of plants, wings of different insect groups.

Incisors of beavers, tusks of elephants

6. What are analogous structures? List an example. (1 pt)

Similar structures that evolved independently, not via common ancestry

Limbs of octopus, grasshopper, and vertebrate

7. How do analogous structures evolve? (1 pt)

If two species face a similar problem, challenge or opportunity, evolution may end up shaping them both in similar ways.

In terms of forelimb homologies, be familiar with the sharded bones below: humerus, ulna, radias, carpals, phalanges (phalanges are in red in the figure below)



**Lab Assignment – Part 3 (8 pts)**

1. Examine homologies on this website (and play! Zoom in and out): (2 pts)

Wheel of forelimb morphology: <https://sketchfab.com/3d-models/wheel-of-forelimb-homology-vertebrate-classes-81ebf9ee17ef4cb19d3b2ae49b8a1799>

Describe morphological changes that you see depending on vertebrate “class” or large taxonomic group. What major trends do you see within and between taxonomic groups?

Effort based grading here. No right/wrong answer necessarily. Full 2 pts for students that work at this reponses. Less for “meh” responses, your call.

2. Examine homologies on this website (and play! Zoom in and out): (2 pts)

Two worlds, one forelimb: <https://sketchfab.com/3d-models/wheel-of-homology-two-worlds-one-forelimb-d26e5f9c3f544cc78e75bfe4df195acc>

Describe morphological changes that you see depending in which “world” the animals are located in. In your response, be sure to examine the different taxonomic groups (click on the numbers near the forelimbs) and describe how reptiles, birds (other reptiles), and mammals differ in their mophologies.

Effort based grading here. No right/wrong answer necessarily. Full 2 pts for students that work at this reponses. Less for “meh” responses, your call.

3. Examine homologies on this website (and play! Zoom in and out): (4 pts)

From A to Chimpanzee: <https://sketchfab.com/3d-models/wheel-of-homology-from-a-to-chimpanzee-13f0aad153744dc1b37592d10869aad3>

Looking at each species in this homology wheel, what type of locomotion do you think each species exhibits and why? Effort based grading; see how much effort students give

1. Rainbow trout, swims, presence and spread of fin rays

2. Coelacanth, swims, presence and spread of fin rays

3. Australian lungfish, swims/crawls, modified carpals

4. Sauripterus taylori, swims/craws, presence of fin rays and modified carpals (primitive tetrapod features; https://www.uchicagomedicine.org/forefront/biological-sciences-articles/how-fish-fins-evolved-just-before-the-transition-to-land)

5. Tiktaalik roseae swims/craws, presence of fin rays and modified carpals (primitive tetrapod features; https://www.uchicagomedicine.org/forefront/biological-sciences-articles/how-fish-fins-evolved-just-before-the-transition-to-land)

6. Hairy frog, walks/jumps, phalanges, carpals = distinct wrist, elogated humerus, radius, & ulna

7. Japanese giant salamander, sprawling walker; spread out bones of hand & forelimb

8. Emerald tree monitor, walker/climber (swim?), elongated phalanges, robust forelimb bones

9. Green sea turtle, swim/walk, elongated and wide phalanges, robust/short forelimbs

10. Eastern box turtle, walks, short robust phalanges, big humerus (bones support weight on land)

11. American alligator, walks/swims, elongage phalanges, strong/robus forelimb bones

12. Atlantic puffin, swims/flies (in water), unique bone fusions, elongated hand bones for feather attachment

13. Galapagos penguin, swims/flies (in water), unique bone fusions, elongated hand bones for feather attachment, robust bones to deal with pressure of the water

14. Bald eagle, flies, unique bone fusions, elongated hand bones & ulna for feather attachment. Long for soaring

15. White throated switch, flies, unique bone fusions, elongated hand bones. Robust for rapid flight.

16. Platypus, walks/swims, elongage phalanges, strong/robus forelimb bones

17. Short beaked echida, walks/swims (proposed aquatic ancestor), elongage phalanges, strong/robus forelimb bones (check out olecranon process; digger)

18. Orca, swims, spaced out phalanges, robust, short forelimb bones to deal with pressure of the water. Fast swimmer

19. Humpback whale, swims, spaced out phalanges, robust, short forelimb bones to deal with pressure of the water (diff morphology than Orca supports slower swimmer)

20. Poitou donkey, Terrestrial runner/walker (fast?), elongated forelimb ones, unique fusions

21. Tapir, Terrestrial walker (slow), long phalanges to support weight

22. Vampire bat, flight, long thin phalanges and forelimb bones to support wing membrane

23. Star nosed mole, walks/digs (check out olecranon process; digger), olecranon process, robus short bones

24. Gray tree rat, likely many things!, Nothing really exceptional about the bones for unique locomotion

25. Chimpanzee, walk/climb/arboreal, ulna and radius not fused, roundend ends of long

More images here: <https://sketchfab.com/ufherps/collections/forelimb-homology>

Mammal forelimbs: <https://sketchfab.com/3d-models/mammals-on-the-move-forelimb-adaptations-edc963a36388486ab3f27f1a2b92b267>