

# Mammalogy (BIOEE 451)

## Lab 1 – Skull and Dentition I

### Mammalogy in the Field

### Mammalian Diversity: Order Monotremata

#### Business:

1. **Lab safety** – Cornell policy is to not permit food or drink in the lab. Some of the specimens that we will examine have been preserved with chemicals (including arsenic). Short term handling of these specimens does not pose a health risk, but you should wash your hands after each lab.
2. **Care of specimens** – Many of the specimens that you will examine are quite literally priceless, and the rest are darn expensive. Please handle them gently. Always stroke fur in the direction that it lies, and don't use pens or pencils to point at specimens (probes are provided for your pointing needs). Be particularly careful to protect the teeth, which are quite brittle. Specimens should always be placed in the padded trays that are provided. Dried study skins are particularly fragile; never pick them up by the foot or tail and be careful to place them belly down after examination. If anything falls off of a specimen (tooth, label, foot, etc.), report it to the TA immediately so that it can be reattached.
3. **Lab assignments** – There are two major assignments associated with the lab, a weekly field journal and a paper on animal behavior. Please see handouts for additional information.
4. **How the labs work** – At each lab there will be a series of stations for you and your lab partners to work through using the information in the lab handout. Start at any station and work at your own pace, but make sure that you make it to all the stations before the lab ends at 4:25. Take notes and sketch important structures. The relevant sections in your lab (Martin et al.) and lecture (Vaughan et al.) texts will be referenced throughout each handout. Refer to your lab text as you study the material at each station. Practical questions will not be drawn from the lecture text, but you may find it a useful supplement. In some cases lab stations will be available at subsequent labs (these will be indicated), and prior to each practical we will organize a time for relevant material to be reviewed. Anything in the lab handout, station displays, and referenced sections of the lab manual will be fair game for practicals. Remember, you are your own best teachers! Work together to master the material.

#### **Station 1 - Cranial characteristics of mammals:**

Mammals are descended from a group of reptiles called the therapsids, which were distinguished from other reptiles based on the number of temporal openings in their skulls. The skulls of these ancestors of mammals were **synapsid**, meaning that they had a single temporal opening. Other reptiles were either **anapsid** (no temporal openings) or **diapsid** (2 temporal openings). The modern mammalian skull is highly derived relative to those of its therapsid ancestors, but it is still possible to see the single synapsid opening in the space that lies between the **zygomatic arch** and the **braincase** and falls behind the **orbit**.

- At this station there are examples of anapsid, synapsid, and diapsid skulls. Determine which skull represents each type, and identify the temporal openings in each (if present). Don't include the orbits in your count.

A major feature of mammalian evolution was a trend toward increased skeletal efficiency through the reduction of the number and size of bones. An excellent example of this trend is seen in the **mandible** (lower jaw).

- Examine the mandibles of the alligator and the dog, paying particular attention to the **suture** lines that indicate where two separate bones come together. How many bones make up the alligator mandible? What about the dog?

As the synapsid reptiles evolved, some jaw bones became co-opted for other purposes. Over time the two bones that once formed the articulation between the upper (**quadrate**) and lower (**articular**) jaws shrank and moved into the inner ear to become the **incus** and the **malleus**, respectively.

- Find the quadrate and articular on the alligator skull.
- Find the incus and malleus in the model of the ear.
- Which bone of the inner ear is found in both reptiles and mammals?

Another difference between the skulls of reptiles and mammals is the fact that reptiles have a single **occipital condyle** while mammals have two. This important innovation gives mammals an increased range of head motion, which has significant implications for predator avoidance, prey acquisition, and other aspects of mammalian life history.

- Examine the differences between the occipital condyles of the skulls at the station.

### **Station 2 – Cranial and mandibular bones:**

(Martin et al. – Chapter 2; Vaughan et al. – pp. 24-26)

Sometimes there's nothing for it but to memorize. It is very important to learn the names of morphological features so that we can discuss them. Follow the text in your lab manual (pp. 6-9) to identify the bones and major features of the dog skull. As you make identifications, label the bones in the figure on page 7. When you are finished, confirm your IDs with the answer key on pp. 11-12. *Please remember to use the probes that are provided rather than your pencils and pens when pointing at the skulls!*

### **Station 3 – Heterodonty and dental formulae:**

(Martin et al. – Chapter 3; Vaughan et al. – pp. 26-32;)

The reptilian ancestors of mammals were **homodont**, meaning that their teeth were all essentially identical and had a single function (i.e. to hold prey so it could be swallowed whole). In contrast, mammalian teeth are **heterodont**, meaning that they have diversified into different types that perform different functions. This has opened the door to numerous mammalian innovations in dental morphology, which has allowed mammals to exploit a much broader range of food resources than their ancestors. The four major tooth types in mammals are the **incisors** (1 root), **canines** (1 root), **premolars** (1, 2, or 3 roots), and **molars** (3 roots – upper, 2 roots – lower). Read about how these different types of teeth are used (lab manual pp. 14-15) and identify them in the skulls at this station. Note that the upper incisors are always rooted in the premaxilla, and the upper canines (if present) are the most anterior teeth in the maxilla. In some taxa, canines are lacking, leaving a wide gap (**diastema**) between the incisors and the premolars. The premolars and molars can be difficult to distinguish in adult individuals, so they are sometimes referred to collectively as **cheek teeth**.

Mammalogists use dental formulae to characterize the number of each tooth type in mammals. Dental formulae may be written in different ways, but in this class we will write them for one half of the jaw and use the letters I, C, P, and M to indicate tooth type. For example, the dental formula for a dog would be written: I 3/3 C 1/1 P 4/4 M 2/3. In each fraction, the numerator indicates the number of teeth that are in one half of the upper jaw and the denominator indicates the number of teeth in one half of the lower jaw. In cases where it is impossible to tell which teeth are premolars and which are molars, the dental

formula can be written to combine the cheek teeth. For example, in a dog this would be written: I 3/3 C 1/1 P+M 6/7.

A different shorthand method is used to identify specific teeth. This shorthand varies among mammalogists, but we will use the following convention. Upper teeth are indicated by an uppercase initial and lower teeth are indicated by a lowercase initial. In either case, the initial is followed by a number indicating the tooth's position. Tooth position is counted from anterior to posterior. In the case of a dog, the upper teeth would be described as follows, starting from the anterior-most tooth: I1, I2, I3, C1, P1, P2, P3, P4, M1, M2. How would a list of the lower teeth differ?

- Review the section in the lab manual on dental formulas (pp. 18-20). Examine the skulls at this station and write dental formulas for each. If asked, you should be able to identify a tooth's type and its position in any skull.

#### **Station 4 – Ancestral mammalian molars (to return in Lab 2):**

(Martin et al. – pp. 15-16; Vaughan et al. – pp. 26-32)

Mammalian molars have diversified into a startling variety of forms, permitting mammals to take advantage of a huge range of specialized diets. However, all this diversity began with the **tribosphenic** molar. This ancestral tooth design is retained in primitive marsupials and placentals, giving us an excellent opportunity to learn the names and positions of the most important features that eventually evolved into our own versatile chompers.

- Use the labeled diagrams in Martin et al. and at the station to identify the major cusps of the upper molars (**protocone, paracone, metacone**) in the opossum, shrew, and mole skulls. Be careful not to be confused by the **stylar shelf**, a ledge with several small cusps situated labial to the paracone and metacone. You will need the dissecting scope for the smaller skulls.
- Do the same for the **protoconid, paraconid, metaconid, entoconid, hypoconulid, and hypoconid** of the lower molars. You should also be able to identify the **trigon, trigonid, and talonid**.
- Fit the lower and upper jaws of the opossum together to see that the protocone occludes with the **talonid basin**, a depression in the center of the talonid. What is the depression in the trigonid called?

As you examine the teeth, keep in mind the relative position of each cusp. You should know whether or not a given cusp or feature is **anterior/posterior** or **lingual/labial** to another part of the tooth. As teeth continued to evolve beyond the basic design of the tribosphenic molar, they changed shape with the addition of new cusps and ridges. An important modification came with the addition of the **hypocone** in the upper molars, which resulted in square teeth. When you get to Station 5, look for the hypocone in the molars adapted to omnivory.

#### **Station 5 – Dental modifications associated with diet (to return in Lab 2):**

(Martin et al. – pp. 17-18; Vaughan et al. – pp. 26-32)

Though the tribosphenic molars were a major innovation for mammals, allowing them to process food much more efficiently than was possible with the primitive homodont teeth of their ancestors, molars continued to evolve and diversify. Molars became specialized for specific diets, making it possible for us to tell much about how a mammal lives simply by looking at its teeth. We identify three major dietary strategies in mammals: **herbivory, carnivory, and omnivory**.

In general, the molars of herbivores wear down as they grind up coarse plant material. Natural selection has therefore led them to have continuously growing teeth with extremely high **crowns** (the part of the

tooth that sits above the gums – usually covered with **enamel**). These high-crowned (**hypsodont**) molars have a relatively flat occlusal surface because the ancestral cusps have become connected by a series of laterally running ridges (**lophs**). Thus, many herbivores have **lophodont** teeth. In a variation on the lophodont theme, some herbivores have crescent shaped ridges in their molars. This unique design is termed **selenodont**.

- Examine the skulls of the horse, deer, and beaver (a rodent). Which of these are lophodont? Which are selenodont? Note the relative height of the crowns of these animals compared to the other skulls at this station.

Other dental modifications associated with herbivory include the loss of canines or incisors in some taxa. Are any of these teeth missing from the herbivores at this station? Which ones? Note the diastema between the incisors and premolars of the beaver. The beaver skull illustrates an important adaptation of rodents to their gnawing lifestyle. The ever-growing incisors only have enamel on the anterior surface, allowing the softer **dentine** behind to wear away faster. This allows the tooth to be sharpened continually as the animal gnaws. Examine the beaver incisors to see how this sharpening takes place. The herbivores at this station also exhibit molarization of the premolars, another adaptation to their diet. Can you tell which cheek teeth are molars and which are premolars? What if you know their dental formulae? Beaver – I 1/1, C 0/0, P 1/1, M 3/3; White-tailed deer – I 0/3, C 0/1, P 3/3, M 3/3; Horse – I 3/3, C 0-1/0-1, P 3-4/3-4, M 3/3. Note that in horses the number of canines and premolars may vary among individuals.

Aside from prominent canines, which are used to hold and kill prey, the primary dental modification for a carnivorous lifestyle was the development of the **carnassial apparatus** (sometimes termed the carnassial pair). This refers to teeth P4 and m1, which occlude tightly together to act as shears for slicing flesh. In some cases (e.g. hyena) these teeth have become exceptionally robust for use in crushing bones and other hard food items.

- Examine the carnivore skulls at this station. Note how tightly the carnassial apparatus fits together, and how the two teeth act in a scissor-like fashion.

Omnivores, like carnivores, generally have low-crowned (**brachyodont**) teeth. Because these teeth must be capable of processing a broad range of food, they are generally intermediate in form between the teeth of herbivores and carnivores. This compromise has resulted in **bunodont** teeth, meaning that they are low with rounded cusps. Humans and pigs are classic examples of omnivores with bunodont teeth.

### **Station 6 – Extreme dental modifications (to return in Lab 2):**

So far we have examined some of the most common dental patterns seen in mammals. At this station we have assembled some examples of particularly bizarre or impressive dental specializations. As you examine these specimens, consider what you have learned so far about the types of teeth and how they have become modified for certain dietary needs. Based on what you know, could you make predictions about how these animals live or what they might eat?

Some examples of extreme modifications:

Elephant tusk – modified incisor

Walrus tusk – enlarged canine

Crabeater seal cheek teeth – used to strain krill from water

Flying lemur comb-like incisors – used for grooming

Anteater lacking teeth entirely – no need for teeth when you “drink” ants

### **Station 7 – Field methods in mammalogy**

Enough about teeth already! In order to study mammals it is necessary to go into the field to find them. This station is intended to give you a sense of the tools that field mammalogists might employ to get closer to their study organisms. Live traps such as the pit traps, aluminum Shermans, and larger cage traps are important tools for mammal ecologists, allowing animals to be caught, measured, marked, and released without damaging the local population. Kill traps such as the Museum Specials, rat traps, and conibears are important tools for researchers that are interested in surveying and archiving diversity. Killing animals is not something that researchers take lightly, and we have an ethical imperative to maximize the value of any specimen that is taken from the field. Modern mammal collectors accomplish this by preserving voucher specimens (skins, skulls, skeletons) for morphological studies and tissue samples (e.g. heart, liver, kidney, muscle) for DNA analyses, as well as standard measurements and locality data. They also conduct full necropsies to remove and preserve internal and external parasites, which can support additional avenues of research. All specimens should be archived in natural history museums where they can be made available to the scientific community. In this way, focused collecting for museums reduces the need for repeated, wasteful trapping that may impact populations negatively.

Mammalogists use methods other than traps to study animals. Some examples include hair snares (devices that catch fur as animals pass and allow mammalogists to monitor diversity), track plates (treated plates that make track impressions as animals walk over them), mist nets (for catching bats), and audio recording equipment (for studying vocalizations).

- Examine the tools at this station. Please be careful; the traps are real and can pack a wallop! What would a mammalogist need to know about a mammal's life history in order to use them effectively (e.g. would a mist net catch many bats at noon)?

### **Station 8 – Mammalian diversity – Order Monotremata:**

(Martin et al. – Chapter 10; Vaughan et al. – Chapter 5)

Classification: **Class Mammalia**

Subclass Prototheria

**Order Monotremata**

**Family Ornithorhynchidae**

**Family Tachyglossidae**

The monotremes are the most primitive of the mammals. The name Monotremata means “one-holed”, which is a reference to the cloaca, a single opening through which feces, urine, and eggs all pass. The cloaca is a primitive feature shared by other vertebrates, but is extremely rare in other mammals. Like reptiles, monotremes have **cervical ribs**, and like marsupials, they have a pair of **epipubic bones** attached to the front of the **pelvis**. Their relatively wide stance is also suggestive of the posture of reptiles and amphibians, rather than most mammals. Perhaps the most peculiar characteristic that unites these mammals with our reptilian ancestors is the fact that they lay eggs. Though primitive, monotremes are highly specialized. Many bones in the skull are reduced or absent (e.g. jugal, lacrimal bones, auditory bullae), and adults lack teeth (**edentate**). All males (and some female echidnas) have a sharp, **hollow spur** on their hind limbs. In *Ornithorhynchus* a **venom gland** is connected to the spur. Like all mammals, monotremes have mammary glands and feed their young milk. However, they lack nipples or teats. Milk is secreted into the fur, where it is sucked up by the young.

- Examine the specimens at this station as you read about monotremes. Identify the epipubic bones on the echidna skeleton. Can you identify the cranial bones, and see how some bones have been reduced or lost? Note the horny plates on the palate of the echidna skull that replace teeth for grinding food. What morphological features are likely to be adaptations to a semi-aquatic or burrowing lifestyle?

### **Order Monotremata, Family Ornithorhynchidae**

- Distinguishing characters: webbed feet; leathery duck-like bill, dorso-ventrally flattened
- Number of species: 1
- Representative species: Duck-billed platypus, *Ornithorhynchus anatinus*
- Geographic distribution: eastern Australia and Tasmania
- Diet: aquatic crustaceans, insect larvae, some plants; since adults lack teeth, food is ground against horny plates in beak
- Habitat: freshwater environments; live in burrows (up to 20m long) along forested banks of lakes, rivers, and mountain streams
- Behavior: highly aquatic; forages in rocks and sediment at bottom of streams, lakes; excellent diggers
- Size: 47-56 cm; 1.3-2.3 kg
- Reproduction: female incubates 1-3 eggs 6-10 days; nursing lasts for ~5 months
- Lifespan: 10 years; 17 recorded in captivity
- Other notes: young have teeth, but lose them when they become adults; a “tooth” on the tip of the bill is used by young to cut out of the egg; detects electrical impulses emitted by prey to find them underwater; has 10 sex chromosomes

### **Order Monotremata, Family Tachyglossidae**

- Distinguishing characters: sharp spines that lack barbs, long rostrum with long sticky tongue, powerful forelimbs and large claws for digging; spiny ridges on back of palate and tongue for grinding food
- Number of species: 4
- Representative species: Short-beaked echidna, *Tachyglossus aculeatus*  
Long-beaked echidna, *Zaglossus bruijnii*
- Geographic distribution: Australia and New Guinea
- Diet: *Tachyglossus* – small invertebrates, primarily ants and termites  
*Zaglossus* – worms and insect larvae
- Habitat: semi-arid lowlands to highland forests
- Behavior: usually solitary; powerful diggers – can escape predators by burrowing and use spines to wedge themselves in for protection; curl into a ball with spines out when harassed; may be nocturnal or diurnal
- Size: 30-90 cm; 2.5-10 kg
- Reproduction: female incubates 1 egg ~10 days; female carries egg (7-10 days) and newly hatched offspring (6-8 weeks) in temporary pouch until spines begin to harden; nursing lasts ~7 months
- Lifespan: 30 years recorded in captivity; uncertain in the wild
- Other notes: *Tachyglossus* rostrum bears electroreceptors as in platypus; *Zaglossus* will catch prey by grasping it with its barbed tongue; hibernate during winter