Lab objectives
The objectives of today’s lab are to:
1. Learn the basic osteology of the major reptilian groups.
2. Learn the differences in osteology among these major groups.
3. Consider why the differences that you see have evolved.
Today’s lab is the first of two reptile anatomy labs. It will introduce you to some basic osteology of reptilian groups, compare osteology of different “reptiles”, and reinforce some of the material learned in lecture. If you have time left after you finish today’s exercises, you are encouraged to review material from the previous labs. Keep in mind that your lab final is quickly approaching, so make sure that you use your time wisely.

Tips for learning the material
Anatomy is a very detailed and precise field of science. Small differences matter and every structure has a name. Although we are not learning any new species during this lab period, there is a considerable amount of material to learn, so spend the time wisely. You should already be familiar with the external anatomy of the “reptiles”, so the next two labs will focus on the internal anatomy. This week you will study osteology (the study of bones), and next week you will study soft tissues.

To learn the material, work through everything on display systematically. Pay attention to how bones are arranged in each animal. Also be aware of how these animals’ skeletons differ from one another.

Use the concept of homology to help you throughout. Most of the osteological structures that you will be learning are not novel to each clade, but homologous among clades. This means that a lizard frontal bone and a turtle frontal bone look similar (not the same), and are in a similar location within the body. This will help you to identify and learn structures, but is also useful in studying the evolution of the animals covered.
Exercise 1: Cranial Osteology
There are several skulls on display for you to look at: a sea turtle (Cheloniidae), a snapping turtle (Chelydridae), a few other turtles, two alligators (Alligator mississippiensis, A. sinensis), a crocodile (Osteolaemus tetraspis), a Tuatara (Sphenodon punctatus), a marine iguana (mounted on a complete skeleton – Amblyrhinchus cristatus), a green iguana (also on a skeleton – Iguana iguana), a bearded dragon (Pogona vitticeps), two unidentified lizard skulls, two small vipers (please do not touch this one – it is extremely fragile and may still contain venom), a large python (Python reticulatus) and a cat (Felis catus). These skulls are instructive of many evolutionary patterns and include examples of anapsid, synapsid and diapsid amniotes.

What are the differences between a synapsid, anapsid and diapsid skull?

Which of the species listed above belongs to each group?

Anapsid:

Synapsid:

Diapsid:

Homology of the major fenestrae of the skull can be confirmed by noting which bones line each opening (fenestra). Instead of having you simply memorize all of the bones in these skulls, we will focus on several bones that are important in distinguishing them. The lower temporal fenestra is lined by three bones: postorbital, squamosal and jugal. In a diapsid, the upper temporal fenestra is also lined by three bones: postorbital, squamosal and parietal. One other bone that is important to know is the frontal; it makes up a large portion of the roof of the skull and is a good landmark. The frontal is a single, medial bone that lies in between the orbits. The parietal is a large bone immediately posterior to the frontal. Beware that in the cat both the frontal and parietal are paired bones with a medial suture. The frontal and parietals can be paired or fused, depending on taxon.

In the skulls on display, locate the frontals and parietals. In which of the skulls are the frontals paired? Fused? How about the parietals?
The postorbital generally shares a suture with the anterolateral edge of the parietal, and, as its name suggests, also lines the orbit posteriorly. The squamosal shares a suture with the posterolateral edge of the parietal, and a posterior one with the postorbital. The jugal lines the posteroventral edge of the orbit, and articulates with the postorbital. It sometimes also articulates with the squamosal, although at other times it articulates with the quadratojugal. A final bone that you should know is the one that suspends the lower jaw: the quadrate. The best way to identify the quadrate is that it articulates with the lower jaw and is in the posterior part of the skull.

Identify the postorbital, squamosal, parietal, jugal and quadrate in the skulls on display. As a hint, note that the jugal is absent in lizards (see below). Use the detailed anatomical descriptions in the preceding paragraphs to identify them. You will have to rely on the descriptions especially with the turtle skull because it has no temporal fenestrae to use as further landmarks. Find the orbits and go from there. Any and all of these might show up on an exam.

For the diapsid condition, the crocodylians and the Tuatara have a pretty typical arrangement of bones (as described above). However, lizards and snakes have a modified diapsid condition. In lizards, the bar formed by the jugal, connecting to the quadrate is absent. This means that there is only the dorsal-most fenestra present and the ventral fenestra is expressed simply as an open region of the skull. This allows the quadrate to move more freely and is what is known as a streptostylic condition. You can confirm that it is indeed the ventral fenestra that is absent, not the dorsal one, by identifying the bones lining it. The snake has a further reduction of bones posterior to the orbit, and has just an open region in the skull, as opposed to discrete fenestrae.

How is a lizard’s skull modified relative to that of the Tuatara?

How is the skull of the snake further modified relative to what you see in the lizards?
Note that the cat has a highly derived morphology so the homologous bones look very different and are called different things. The bones are labeled for you on the diagram of the cat skull below. Confirm them on the actual skull. Notice that in the cat, there is a temporal bone that has a zygomatic process and a squamous portion. It is formed from the fusion of several other bones. You will not need to know the bones in the cat skull, but you do need to know where its temporal fenestra is. You will also need to know the bones described above in the other skulls. To help you with this, it is recommended that you draw or photograph the skulls and then label the bones.

Why is the cat skull included as part of a herpetology anatomy lab?

The skulls have many more features than a few fenestrae, and it is important to consider how they came to be the way they are. Not having any temporal fenestrae, space for muscles in turtle skulls must be made in other ways. **Emargination** is the degree to which the skull is reduced in the posterodorsal region to accommodate jaw closing muscles. Compare the sea turtle skull with the other turtle skulls on display. Compare the level of emargination between all of these turtle skulls.

**Which skull has the highest degree of emargination?**

More emargination means more space for muscles that close the jaw and this has various ecological correlates.

**What differences in diet would you expect between the two turtles on display, given the degree of emargination in each?**
Move on to the crocodylian skulls. Notice the high degree of fusion among the bones, resulting in a very solid structure. These are some adaptations to resist large forces that are exerted on the skull when the alligator is killing and eating large prey. On the dorsal side, find the external nares, or nostrils. Flip the skull over and look at its ventral side. Find the choanae, or internal nostrils. Where are they (use anatomical terms, and start with the real skull before moving on to the replicas)?

The secondary palate is a bony division that separates the oral cavity from the nasal cavity. The choanae mark the posterior extent of the secondary palate. Mammals also have a secondary palate. Touch the roof of your mouth with your tongue – you’re feeling the secondary palate. Now locate the secondary palate on the alligator skull.

Next consider the degree of kinesis in the skulls in lab, including that of the viper. Cranial kinesis refers to the amount of movement possible within the skull. We humans have little to no cranial kinesis – our skull is a solid structure composed of multiple but closely fused bones. The only movement occurs at the jaw joint. This is the same situation as in the cat. Take a look at the cat skull and confirm this for yourself. Cranial kinesis increases with the number of discrete, unfused bones in the skull. In highly kinetic skulls, there is more connective tissue (particularly ligaments) that holds the bones together.

Examine the skulls on display: the turtles, lizards, snakes, and crocodylians. Consider the degree of cranial kinesis in each. Where would you expect movement in each skull to occur?
What differences do you see between a lizard skull, python skull, and viper skull that would result in different amounts of cranial kinesis in each?

Now compare the skull of *Pogona vitticeps* to that of the other lizard skulls. *P. vitticeps* has what is called acrodont dentition, while the latter have pleurodont dentition. The acrodont condition has teeth that are in a groove in the jaw, attached on both lingual and labial sides. Teeth are also fused to each other anteriorly and posteriorly, and no replacement of teeth occurs. The "Agamidae" and Chamaeleonidae are acrodont. All other lizards are pleurodont, where teeth are not fused to one another and teeth attach only on the labial side directly to the jaw. On the lingual side, the teeth are attached to a low bony ridge. Pleurodonts replace their teeth throughout their lives.

From examining the lizard skulls, describe the differences between these two forms of dentition in your own words.

Which dentition seems more robust? Why?

What is meant by the terms "labial" and "lingual"? (hint: they are anatomical positions, like "anterior" or "caudal".)
The crocodylians have a different type of dentition, called thecodont. Describe how this differs from the two types of lizard dentition. Why do you think that crocodylians have this type of dentition?

**Exercise 2: Postcranial Osteology**

The postcranial skeleton consists of everything posterior to the skull and jaws. On display, we have several postcranial skeletons: a turtle, a green iguana (*Iguana iguana*), a marine iguana (*Amblyrhichus cristatus*) and a small snake.

Examine the turtle skeleton and the turtle shells on display. There are many notable traits that appear nowhere else among vertebrates. The shell is most striking and has a dorsal **carapace** and a ventral **plastron**. These two halves of the shell are connected on either side by the **bridge**. The shell is made of bone and overlaid with keratinous **scutes**. Examine the shell without scutes and that with the scutes peeling off it. Notice that the impressions from scute edges on the shell without scutes do not coincide with the sutures between the bones. In the other carapace, the scute and bone edges match more closely. A mismatch in scute and bone edges is one indication of different developmental origins of the shell bones and scutes.

The carapace of the shell is composed of **neural** bones that form the midline row of bones. Internally, **note that the vertebrae are fused to the neurals**. Immediately lateral to the neurals are the **pleural** bones. **Note that the ribs are fused to the pleurals**. The **peripheral** bones lie lateral to the pleurals and form the margin of the carapace. The scutes are arranged in much the same way, but have different names: **vertebral, costal and marginal**, in order from medial to lateral. In addition there is a **nuchal** bone and scute at the anterior midline, and a **pygal** bone and **supracaudal** scute at the posterior midline. **Identify all of these bones and scutes on the shells available for examination.**

The plastron is also composed of multiple scutes and bones, but they are arranged quite differently from the carapace. They are arranged in bilaterally symmetrical pairs that meet at the midline, and bones and scutes coincide. Anterior to posterior, the scutes are named as follows: **gular, humeral, pectoral, abdominal, femoral** and **anal**. **Identify all of these on the specimens on display.** Then take a closer look at the plastron of the box turtle (*Terrapene carolina*) on display. It has a **hinge** between the pectoral and abdominal scutes/bones. This hinge allows the animal to firmly close its shell to avoid a predator.

**Finally, notice that the limbs and limb girdles are enclosed within the shell.** This is a major difference between turtles and other vertebrates – the limbs and their girdles are internal to the
ribs. It is a major question in the field of evolutionary development (evo-devo) how this internalization of the limb occurred.

**Compare the situation that you see in the turtle with what you see in the lizard skeleton. Where are the pelvic and pectoral girdles placed in the lizard?**

**What is the pelvic girdle in the turtle and the lizard articulated with?**

Although primates have five types of well-differentiated vertebrae (*cervical, thoracic, lumbar, sacral, and caudal*), many other vertebrates do not have such differentiation. Nevertheless, the squamates do have several types of vertebrae.

**Examine the postcranial skeleton of the lizard, with particular emphasis on the vertebral column. How many different types of vertebrae do you see?**

**Squamates, for instance, lack lumbar vertebrae. How would you distinguish the other types of vertebrae on the lizard skeleton from one another?**
Now look at the snake skeleton. Clearly it has more vertebrae than the lizard, but to what region of the vertebral column have all of these extra vertebrae been added? What kind of vertebra is there the most of in the snake?

Have the relative counts of vertebrae in the lizard and snake changed in other regions as well?

How do the numbers and types of vertebrae compare in the turtle and the lizard?