Primate Phylogeny

Objectives:

- Learn how to create and interpret cladograms.
- Learn some vertebrate skull anatomy.
- Practice measuring using the metric system.
- Become familiar with some primate species and characteristics of primates.

Concepts: A **phylogeny** is the evolutionary history of a taxon. A **phylogenetic tree** is a diagram that shows the history and evolutionary relationships among members of a taxon. A **cladogram** is one type of phylogenetic tree; in a cladogram, taxa that share derived, homologous characters are represented as sharing a common ancestor.

Any cladogram is a hypothesis. With a particular selection of taxa and characters, numerous cladograms are possible. So how is it decided which cladogram is the best supported? The more characters that fit the pattern of the cladogram, the more supported is the hypothesis. Also, an assumption often followed in cladogram construction is that of **parsimony**. One should try to make the simplest cladogram that accounts for all the data. For example, all else being equal, a cladogram in which a derived character evolves just once is considered more likely than a cladogram in which the character evolves several times.

Classification of species into higher categories (into genus, family, order and so on) is generally based on phylogeny. Species that share a common ancestor are placed in the same genus; genera that share a common ancestor are placed in the same family, and so on. Systematists determine common ancestry by comparing taxa, and determining which taxa share the most characteristics. Characteristics with a genetic basis are used; therefore shared characteristics indicate shared genes; the more genes shared, the more closely related two organisms are.

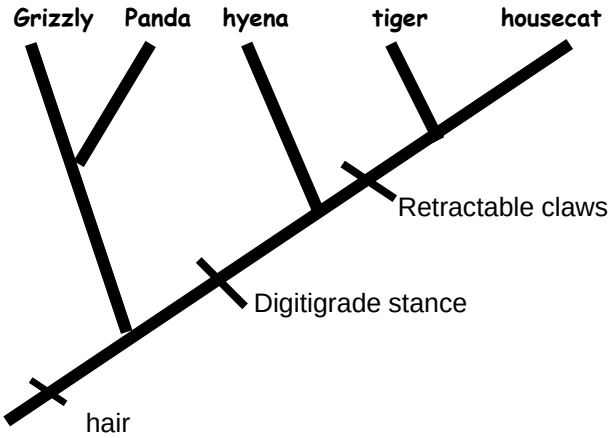

Figure 1: Phylogeny of five mammals

How to interpret a cladogram

Figure 1 shows the phylogeny of five mammals. The tiger and the housecat are the most closely related species in this phylogeny. They share three characteristics, which they inherited from their ancestors. The tiger and the housecat both have retractable claws, a digitigrade stance, and hair.

Among the species shown, the hyena is the closest relative to the tiger and housecat. These three species are all digitigrades, i.e. their digits make contact with the ground as they walk, and their palms do not.

The characteristic 'hair' is placed at the base of the cladogram, indicating all five species have hair, and that the characteristic 'hair' evolved in their common past.

Practice Problem: Construct a cladogram showing the evolutionary relationships among the taxa listed in Table 1. First, decide which taxa have which characters and put the results in Table 1.

TAXA CHARACTERS	dog	kangaroo	lizard	Trout
Hair				
Placenta				
bony limbs				
Vertebra				

Table 1: Characters of selected vertebrate taxa

In making a cladogram from the available data, one of the first things to do is to choose the **outgroup**. The outgroup is a taxon that is related to the other taxa, but is not a member of the group formed by the other taxa. Here, trout is the outgroup. It's related to the other three taxa (all 4 are vertebrates) but the other three are all more closely related to each other than to the trout. (Trout lacks lungs and bony limbs, which the other three all have.)

To determine whether a character is **ancestral** or **derived** compare the character in the ingroup with that of the outgroup. Assume that the character in the outgroup is ancestral. If the character is different in the ingroup, then it is considered derived --[i.e., as evolution took place, the character has changed from its ancestral state to its derived state.[Use 'A' to symbolize the ancestral character and a 'D' to symbolize a derived character. (Campbell et al. use the term 'primitive' rather than 'ancestral.') However, 'primitive' tends to have a negative connotation and 'ancestral,' meaning 'similar to that of the ancestors' is descriptive, but neutral.)

Fill in the Table 2 to reflect whether the characters are ancestral (A) or derived (D).

Table 2: Polarity of characters of selected vertebrate taxa

TAXA CHARACTERS	Dog	kangaroo	lizard	Trout
Hair				
Placenta				
bony limbs				
vertebra				

Draw a cladogram below that conforms with the data in the Table 2. Label the cladogram with the shared, derived characters in the appropriate places.

Introduction: There are about 50,000 species of vertebrates, all of which share common ancestry; two homologies common to all vertebrates are the dorsal hollow nerve cord, and vertebrae. Your assignment today will be to determine the evolutionary relationships of six vertebrates, based on a set of characters listed below.

Skulls from six vertebrates are in the classroom. One species from the Order Rodentia is available, as well as five species from the Order Primates.

Methods: Collect data from the skulls of the six species available. Observe and take measurements on each skull and record the data in Table 3.

Make all measurements in millimeters. Terms are pictured or defined below, as ae instructions on how to take the measurements. Figure 2 illustrate the bones of the human skull. The same names are used for the homologous bones on the other vertebrates.

Do not point to parts of the skulls with the writing end of pens, pencils, or markers.

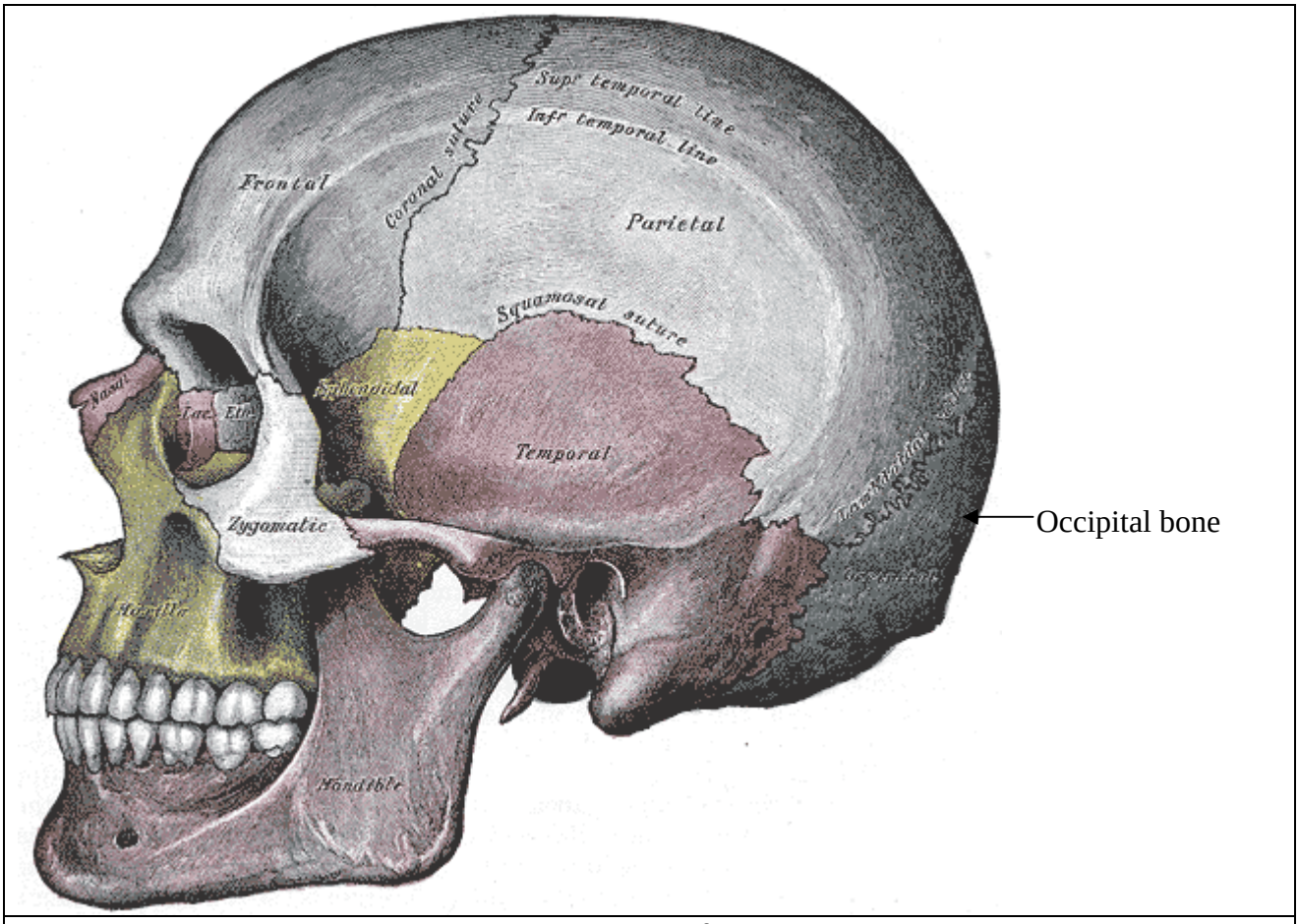

Figure 2: Side view of human skull.
This diagram is from the online edition of the 20th U.S. edition of Gray's Anatomy of the Human Body*, originally published in 1918.*

Instructions on Measuring – measurements of homologous features must be taken in the same way on each skull, so that they are comparable and repeatable.

Eye socket (orbit) – a complete eye socket has a circular ring of bone around the orbit (the location of the eyeball). In an incomplete eye socket, the bone around the orbit does not form a circular ring.

Sagittal crest – a crest at the sagittal suture. The sagittal suture is the joint between the left and right parietal bones. There may be a bony crest at this suture, to which jaw muscles are attached.

Lamboidal crest – a crest at the lamboidal suture. The lamboidal suture is the joint between the parietal bones and the occipital bone; thus, it is found in the posterior half of the skull. In some organisms there may be a bony crest or keel present at this suture, to which muscles are attached.

Foramen magnum – **relative position** – the foramen magnum is the name of the large hole in the base of the skull where the spinal cord enters the skull; the cord then connects to the base of the brain. Establish a relative position of the foramen magnum on the skull.
1. Is the foramen magnum about midway between the incisors and the lamboidal suture ?
2. Is the foramen magnum closer to the incisors than to the lamboidal suture, i.e. is it closer to the front of the skull than it is to the back ?
3. Is the foramen magnum closer to the lamboidal suture than it is to the incisors, i.e. is it closer to the back of the skull than it is to the front ?

Length of maxilla – the maxilla is the upper part of the jaw, and this measure will correspond to the length of the snout. Measure from the posterior edge of the hard palate (the bony roof of the mouth) to the anterior edge of the incisors. You may carefully remove the mandible on all the skulls, except for human, to facilitate this measure.

Bizygomatic arch breadth – the zygomatic arch is the bone bridge just below the orbit. Measure the breadth of the face from the most lateral edge of one zygomatic arch to the most lateral edge of the other zygomatic arch.

Relative snout length – length of maxilla divided by the bizygomatic arch breadth. Do the division. Not all of the organisms have the same body size, so calculating this ratio will take the differeing body sizes into account.

Dental formula -- The dental formula is a series of numbers that reflect the arrangement of the various kinds of teeth on the upper and lower jaws of mammals. (See Figure 3 on next page.)

For example, the dental formula of the house cat (*Felis catus*) is 3/1/3/1 – 3/1/2/1. The skeleton of a house cat is available for observation. The first four numerals reflect the arrangement of teeth on one side of the upper jaw. Starting at the anterior median line on the upper jaw and proceeding posteriorly, there are 3 incisors, 1 canine, 3 pre-molars and 1 molar. The second four numerals reflect the arrangement of teeth in the lower jaw. Starting at the anterior median line and proceeding posteriorly, there are 3 incisors, 1 canine, 2 premolars, and 1 molar. Look at the cat skull to familiarize yourself with the different kinds of teeth. Note that the incisors are in front, and are flat in cross section. Next are the canines, which tend to be conical and pointed. The cheek teeth, the premolars and molars, are for grinding food. The premolars are sharper and substantially smaller than the molars.

Canine diastema – on the maxilla, a space between the incisors and the canine, that leaves room for the opposing canine to fit when the jaw is closed.

Cranial volume -- A crude measure of the volume of each cranium can be measured using beans and beakers. Through the foramen magnum, fill the cranium completely with the beans. While filling, occasionally shake gently so the beans will settle and completely fill the cranium. Once the

cranium is full of beans, decant the beans from the cranium and measure their volume in milliliters using a beaker or graduated cylinder.

Terms used to describe anatomical position: A number of terms are used quite frequently in describing the position of anatomical structures.

Some of these terms (anterior, dorsal, lateral, medial, posterior) are often used relatively. For example, if we say that the diaphragm is anterior to the stomach, it does not mean that you will find the diaphragm at the anterior end of the organism. It means that, once you find the stomach, you will find the diaphragm on the anterior side of the stomach, i.e. the side closest to the anterior end of the animal.

anterior -- the head end of an animal, or in that direction. (e.g. on the pig, the front legs are anterior to the umbilical cord.)

dorsal -- the back or upper side of an animal, or in that direction. (e.g. the vertebral column is dorsal to the heart.)

lateral -- the side, or toward the side.

medial or median -- on or toward the midline of the organism.

posterior -- the tail end of an animal, or in that direction.

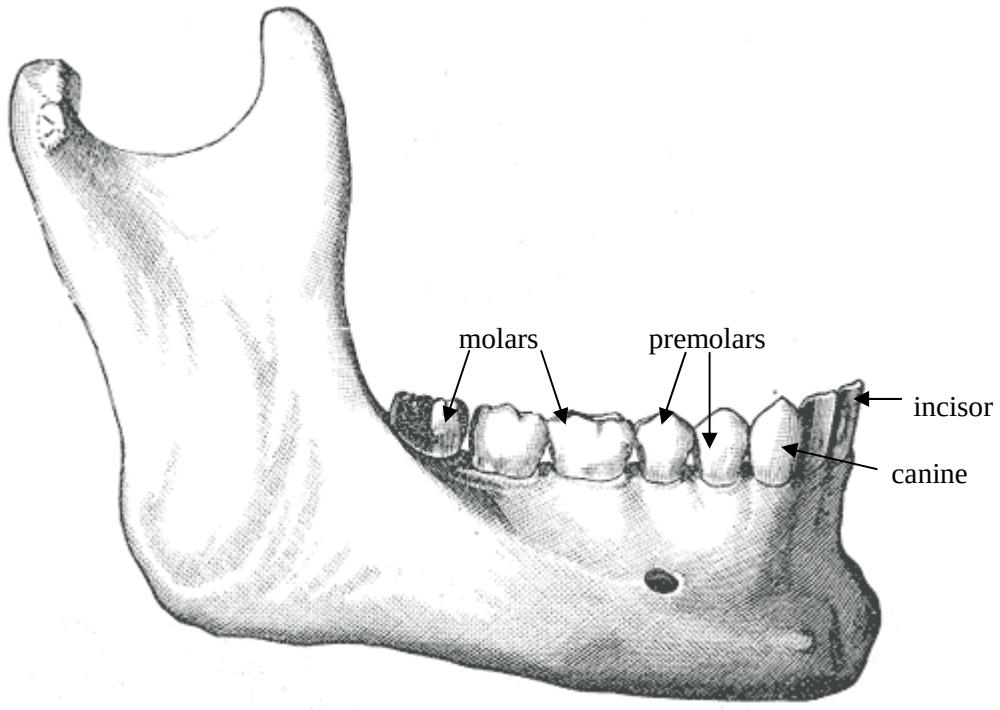

Figure 3: Mandible of human showing arrangement of teeth
This diagram is from the online edition of the 20th U.S. edition of Gray's Anatomy of the Human Body*, originally published in 1918.*

Table 3: Characteristics of selected vertebrates

TAXA CHARACTERS	Orangutan *Pongo pygmaeus*	Fox *Vulpes vulpes*	Rhesus monkey *Macaca mulatta*	Chimpanzee *Pan troglodytes*	Gorilla *Gorilla gorilla*	Human *Homo sapiens*
Complete eye socket?						
Sagital crest present or not (note relative size)						
Lamboidal crest present or not (Note relative size)						
Brow ridge (note relative size)						
Distance from foramen magnum to front						
Distance from foramen magnum to lamboidal suture						
Relative position of the foramen magnum						
Length of maxilla						
Bizygomatic arch breadth						
Relative snout length						
Total number of teeth						
Dental formula						
Relative size of longest canine to longest incisor (Is canine length much longer or about the same size as the incisor?)						
Canine diastema present or not						
Molars and premolars arrangement parallel or arched ?						
Circumference of skull at mid orbit						
Cranial capacity, Milliliters						
Ratio of cranial capacity to circumference of skull						
Number of caudal vertebrae(vertebrae in tail)	3	25	15	2	2	3
Biped or quadruped						

Results: You have quite a bit of information in Table 3. This may be more information than you need to determine the phylogeny of these six species. Also, some of the data may not be helpful in determining phylogeny. Just as other scientists must do, you will have to choose which characters are useful in determining phylogeny, and which are not.

First, decide which characters are most **useful** for discriminating evolutionary relationships. You might consider how difficult it would be from a genetic and/or developmental standpoint for a particular character to change/mutate from one state to another. For example, you could easily imagine a species evolving a somewhat longer canine, but it is probably a much more complicated (and hence less likely) step to go from lacking canines to having canines (or vice versa). List the characters you think are most useful.

Second, choose your outgroup and polarize (i.e. determine whether ancestral or derived) the characters you've chosen as useful.

Third, draw a cladogram that you think is best supported by the data that you have collected and chosen. Remember, the greater the number of shared, derived, homologous characters, the more closely related are the two taxa. Include the derived characters in the appropriate places on the cladogram.

Discussion and Conclusions:

1. For your cladogram, write a paragraph that explains why and how you decided that this was a plausible cladogram. (e.g., address why you chose the characters and outgroup you did.)

2. The cladogram you have made is a hypothesis. What are some ways you could further test this hypothesis ?

3. What are some of the characteristics found in all the Primate skulls ?

4. What are some of the differences between the skull of *Homo sapiens* and the other primates.

5. What character(s) do you see in the human skull that is/are unique to humans?

6. Some species are known only from fossils. Is it possible to know anything about the behavior of such species? For instance, how can one determine from fossil evidence alone, whether a species is a biped or a quadruped? That is, which of the skeletal characters you have recorded from these species is most associated with bipedalism?

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