Section 3 — Ape Physical Characteristics

OVERVIEW

The physical anatomy of apes is essential to their adaptive strategies. Compared to humans, their closest living relatives, ape skeletons are more robust and are aligned for quadrupedalism. Their long, strong arms are characteristic and enable them to move arboreally. The ape dental formula is the same as humans, but there is an emphasis on the front teeth, and the canine teeth can be pronounced in some ape males, primarily for display purposes. Highly intelligent and complex, it follows that the apes have a cranial capacity that is large in comparison to body size.

The apes share some general physical characteristics, and also exhibit some structural differences that are essential to their adaptive life strategies.

Ape skeletons

Skulls

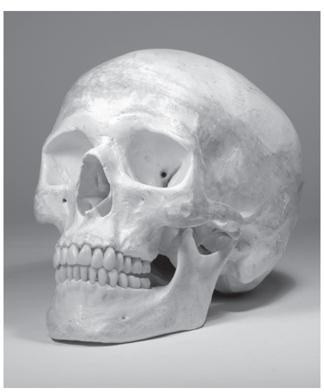
In comparison to human cranial anatomy, apes generally display a more projecting face, a larger brow ridge, a longer face, larger teeth in the front than in the back, larger jaws, and a posteriorly placed **foramen magnum** (the site on the skull where the spinal cord connects). A posteriorly placed foramen magnum is associated with **quadrupedalism**, while an anteriorly placed foramen magnum, like that in humans, is associated with bipedalism (allowing the head to sit atop the spine).

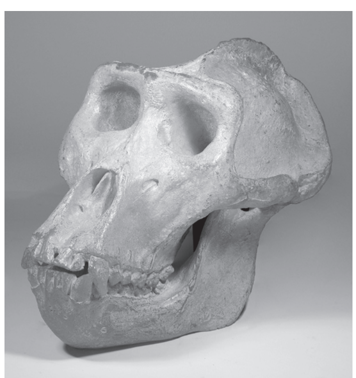
The gorilla has a distinct **sagittal crest** atop the cranium. This bony ridge at the top of the skull is a site for attachment of massive muscles for mastication. The gorilla, a large folivore who eats tough plants, requires such anatomy for its diet.

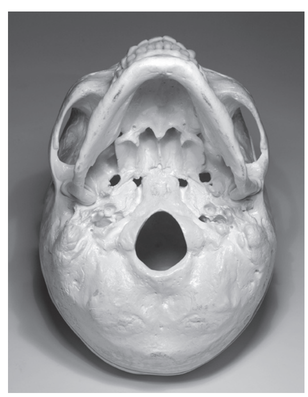
Postcranial

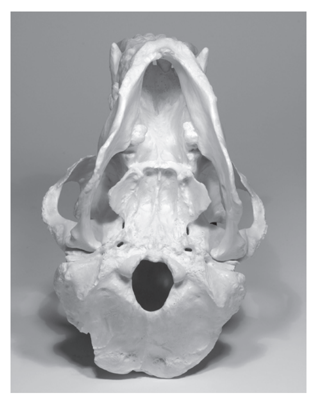
In comparison to human postcranial anatomy (skeletal anatomy that is below the skull), the ape pelvis is longer and narrower. A short, broad, bowl-shaped pelvis, like that of humans, is better adapted for bipedalism, as it better tolerates the pressure and shock of this locomotion pattern.

Photos by Ryan Hawk


Model of a human skull

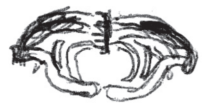

Model of a gorilla skull


Model of a human skull showing the foramen magnum

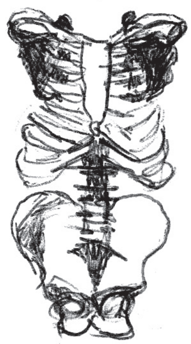

Model of a gorilla skull showing the foramen magnum

Gorilla and human skeletal anatomy, including pelvis and rib cage.

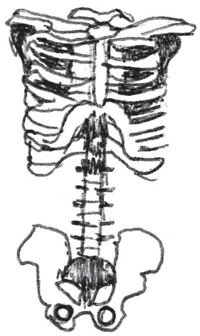
Gorilla pelvis
(top view)



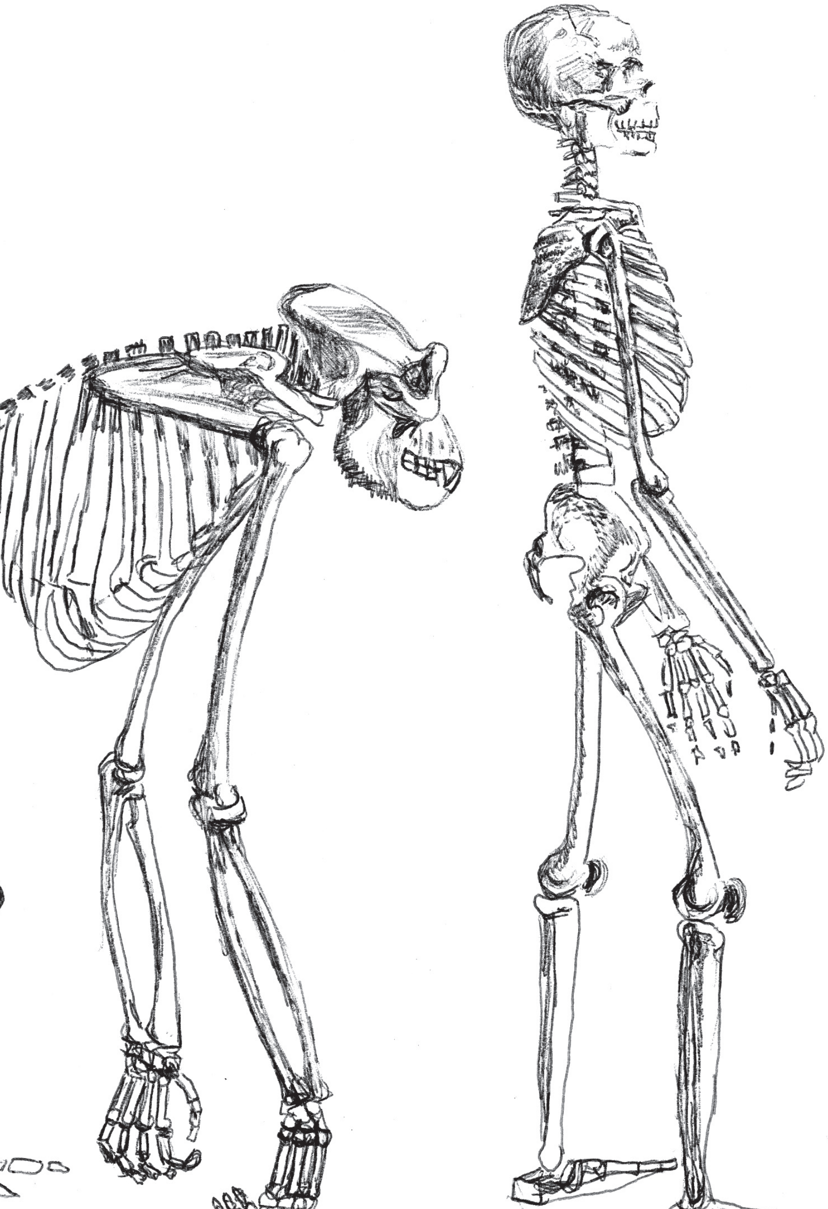
Human pelvis
(top view)



Gorilla rib cage
and pelvis



Human rib cage
and pelvis



Gorilla

Human

Apes tend towards large, barrel-shaped chests, which help balance the center of gravity for quadrupedalism. Also, apes have a relatively straight backbone. The human spine is curved into an S-shape instead of C-shaped (compare illustrations on page 35), making it comfortable and practical to stand upright for extended periods. The ape spine lacks this significant S-shaped curve, however, and thus continued bipedalism again causes high stress and impact.

The ape foot is dexterous, allowing for flexible mobility. Compared to the double-arch of the human foot, the ape foot is flat, though both humans and apes walk **plantigrade** (heel to toe). The **hallux** (big toe) on each ape foot is opposable. The opposability of the hallux and thumb for apes is essential to their grasping abilities and fine motor skills.

Gibbons show exceptionally long, hook-shaped fingers and a shortened thumb. This skeletal structure allows for ease in hooking, gripping, and releasing when brachiating through trees.

Arm length is characteristically longer than leg length in all apes. In fact, ape arms generally extend down to the ankles. These arms are strong as well. It has been said that gorillas have the upper arm strength of six adult human males. Long, strong arms are an adaptive necessity for animals that spend at least part of their lives in trees, locomoting through them, nesting in them, and feeding from them. Though some apes, such as the orangutan, are more arboreal than others, this general evolutionary trend towards long, strong arms allows skillful use of trees, essential components of ape habitats.

Human arms, in comparison, are considerably shorter in relation to body size. In fact, an individual human's arm span can usually be estimated as the total height of the individual, while an ape's arm span is generally larger than its total height.

Table 3. Ape height and arm span

Species	Average Height (m/ft)	Average Arm span (m/ft)
Human*	6 feet (1.8 meters)	6 feet (1.8 meters)
Chimpanzee	3 feet (0.9 meters)	6 feet (1.8 meters)
Gibbon	2 feet (0.6 meters)	7 feet (2.1 meters)
Gorilla	6 feet (1.8 meters)	8 feet (2.4 meters)
Orangutan	5 feet (1.5 meters)	8 feet (2.4 meters)

** National Center for Health Statistics (the number is rounded up from approximate average height of adult males in United States)*

Ape Dentition

All apes share the same dental formula. A dental formula reflects the number of the four teeth types (incisor, canine, premolar and molar) a species has. The dental formula is determined by dividing the entire mouth into equal quadrants, and recording the number of incisors, canines, premolars, and molars found in one of the quadrants of the upper jaw, and then in one of the quadrants of the lower jaw. Multiplying each of these formulas by 2 gives the total number of teeth in the mouth.

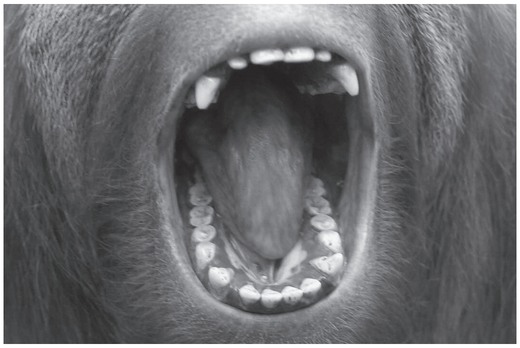
For apes, including humans (with wisdom teeth), the dental formula is: 2.1.2.3 / 2.1.2.3 (=32 total teeth)

The incisors in apes are generally large to support frugivorous diets, as incisors are needed for piercing and stripping fruit. The molars are essential to pulping fruit. In gorillas, the molars are particularly broad for grinding plant materials.

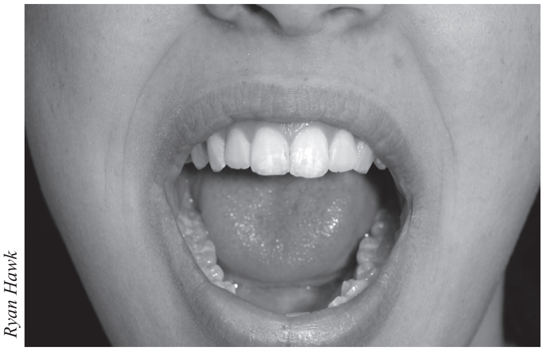
Ape premolars have one cusp, making them useful for sharpening the canine tooth. Human premolars are bicuspid. The two cusps serve to make the human premolar more like a molar, because of the importance of the back teeth in humans (who, compared to apes, have larger back teeth than front teeth for mouth size).

Ape canines can be large and **sexually dimorphic** (different from male to female). In particular, great apes have large canines. These are primarily for display and threat purposes.

Orangutan canines vs. human canines



Dennis Conner



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Beyond Apes: Looking at Other Primates

Primate	General Dental Formula	Total Number of Teeth
Prosimian	2.1.3.3 / 2.1.3.3	36
New World Monkey	2.1.3.3 / 2.1.3.3	36
Old World Monkey	2.1.2.3 / 2.1.2.3	32
Ape	2.1.2.3 / 2.1.2.3	32
Human	2.1.2.3 / 2.1.2.3	32

Prosimian dental specialization
Lemurs and lorises have a dental specialization known as a dental comb. The lower incisors and canines project forward to form the dental comb, which is used for grooming and feeding.

Cranial Capacity

Cranial capacity is a measure of the total volume of the interior of the cranium or braincase. Comparatively among species, a larger cranial capacity in relation to body size is generally associated with enhanced cognitive abilities and behavioral complexity.

Encephalization is the evolutionary trend toward increase in brain size beyond that which would be expected of body size. Apes are characteristically known for their large brains, enhanced cognition and behavioral complexity.

The use of cranial capacity as a measure of intelligence is fiercely debated among scientific circles. To contextualize the relevance of cranial capacity as a measure, brain weight is often divided by body mass, and the quotient is known as the brain:body mass ratio. A higher brain:body mass ratio is associated with higher cognitive abilities and behavioral complexity.

Cranial capacity is discussed here merely because of the attention it has been given over the years in the development of primatology as a field. It is a tool most useful for comparing between species. It is not a useful tool for comparing intelligence within a given species, as there can be considerable variation in relative brain size within a species.

Table 4. Brain Measurements of Humans and African Apes

Species	Average cranial capacity (cubic centimeters)	Approximate brain weight (g)	Average body size (kg)	Brain:Body Mass Ratio
Gorilla	500 cc	500 g	180 kg	1: 0.0028
Chimpanzee	400 cc	420 g	50 kg	1: 0.0084
Humans	1325 cc	1350 g	70 kg	1: 0.02

Sexual Dimorphisms

There are some characteristics that develop in the males of ape species that relate to competition for mates. This type of competition is known as sexual selection. In general, male apes are larger in body size than females of their species, for example. Gibbons do not show much sexual dimorphism in terms of body size, however, as there is considerably less pressure from sexual selection for these pair-bonded species compared to the highly competitive mating world of the great apes. Some species-specific examples of sexual dimorphism follow:

Gorillas—Silverback
Mature adult gorillas begin to grow silver hairs on the back of the body. The **silverback** of a group refers to the dominant male in charge of a harem who displays prominently these silver hairs. The hairs reflect the silverback's rank.

Orangutans—Cheek flange
The cheek flange, or cheek pad, is a fleshy disc that fills out a mature male orangutan's face on both sides. The pads develop as a male matures, and are thought to play a part in sexual selection. The pads may also contribute to voice projection.

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Male orangutan showing cheek flanges

3.1: Interactivity: Apes in Arms **(M,S)**

Materials: Ruler, chalk or string. OR: two youth size t-shirts, ruler, scrap fabric, sewing kit or machine.

Objective: The student will be able to experience ape arm-to-body proportions in order to demonstrate and compare the physical nature of apes to humans.

Procedure:

- There are three different methods you can use to interactively demonstrate ape arm:body proportions with your class:
  1. Draw (or ask a student to draw) the length of an ape's arm span on the chalkboard. Ask student volunteers to fill in the space with their arm span. How many students do you need to fill the same arm span? Repeat using different apes as models.
  2. Measure out (or ask a student to measure out) the length of an ape's arm span using string. Ask student volunteers to hold the string out, and fill in the space with their arm spans. How many students do you need to fill the arm span? Repeat using different apes as models.
  3. Alter two t-shirts with additional fabric so that the sleeve length measures the arm length of two different species of ape. Ask student volunteers to try on the altered t-shirts to demonstrate the difference in human and ape arm length.
- The arms of most apes reach to approximately the animal's ankles. Have students compare this fact to where their arms fall in relationship to their bodies.
- Trivia note: A human's arm span is approximately equal to his/her height.
- Discuss why the arms of apes are so much longer than those of humans. (Some apes are primarily arboreal and others are primarily terrestrial, but all apes spend some time climbing and resting in trees. Long, strong arms aid in brachiating, in dispersing body weight among the branches, and in reaching for food such as fruits and leaves. Humans are primarily terrestrial.)

Assessment Criteria: The student compares arm:body proportions among apes and humans based on the interactive models provided.

Species	Average Height (m/ft)	Average Arm span (m/ft)
Human	6 feet (1.8 meters)	6 feet (1.8 meters)
Chimpanzee	4 feet (1.2 meters)	6 feet (1.8 meters)
Gibbon	3 feet (0.9 meters)	7 feet (2.1 meters)
Gorilla	6 feet (1.8 meters)	8 feet (2.4 meters)
Orangutan	5 feet (1.5 meters)	8 feet (2.4 meters)

Skills used in this activity

- Measuring; comparing measurements
- Modeling of scientific concepts

3.2: How can we use dentition to classify primates? **(M, R, S)**

Materials: Per student: one copy of "How can we use dentition to classify primates?" worksheet, pencil.

Objective: The student will be able to analyze textual information in order to glean important information. The student will be able to perform informed examinations and apply formula in order to describe and classify primate dentition. The student will be able to deduce relationships between dentition and diet.

Procedure:

- Give each student a copy of the accompanying three-page worksheet. You may ask students to review the information on worksheet pages one through two on their own, or review this information together in class.
- Encourage students to highlight, underline or otherwise mark important information. They may also take notes in the margins of the worksheet.
- On page three, students will apply the information and methods discussed in pages one and two. Allow students time to work on their own answers (or work in pairs). They should also take the time to answer the follow-up questions.
- Review the answers as a class. Allow time for discussion about follow-up questions.

Assessment Criteria: The student reads the text for information, and shows the ability to distinguish useful information by marking. The student applies the information, including appropriate formulas, to make informed classifications. The student infers relationships between dentition and diet, and can demonstrate evidence in support.

Extensions

- Working in pairs, have students use a hand-held mirror to examine and draw their own dentition. Have students trade their drawings. How does their dentition compare to another student's? Some students may have third molars (also known as wisdom teeth). TIP: Use a first aid kit mirror, which is designed to fit inside the mouth. You can sanitize the mirror in between student uses.
- Have students eat a variety of foods in the classroom. Try lettuce, cherries, and an apple, for example. Ask students to notice as they bite and chew which teeth they are using, and in what ways? Discuss their observations after each food object.

Teacher Worksheet Key

Primate	Dental Formula	Total # of Teeth	Classification	Diet
1. Orangutan	2.1.2.3 / 2.1.2.3	32	d. Ape	frugivore
2. Ring-tailed lemur	2.1.3.3 / 2.1.3.3	36	a. Prosimian	insectivore
3. Human	2.1.2.3 / 2.1.2.3	32	e. Human	omnivore
4. Mandrill	2.1.2.3 / 2.1.2.3	32	c. OW Monkey	folivore
5. Squirrel monkey	2.1.3.3 / 2.1.3.3	36	b. NW Monkey	frugivore

Skills used in this activity

- Reading for new information and to perform a task
- Analyzing, interpreting, and synthesizing textual information
- Applying mathematical formula
- Classifying based on observation and information
- Deducing relationships between physical and behavioral phenomena (dentition and diet)

Name____ **Date** ____________

Worksheet: How can we use dentition to classify primates?

DIRECTIONS: Read the information below, underlining or highlighting anything you find useful. Then, examine the illustrations. Each reflects the dentition of one of the following primate types: prosimian, New World monkey, Old World monkey, ape or human. On page three, you will match each set of teeth with its correct primate type. Then you will answer the follow-up questions.

Classifying teeth:

There are four primary teeth types, each with a different role. Within a species, these teeth types are uniquely shaped and sized to suit the species' particular diet. These teeth types include:

1. Incisors – the front teeth, used for seizing, stripping, biting and puncturing
2. Canines – located between incisors and premolars, bladelike with varying length and sharpness; used in gripping, stabbing, tearing; can also be used by males for aggressive display behaviors
3. Premolars – located between canines and molars; used for crushing and grinding, in some cases also used to sharpen canines
4. Molars – back teeth, broadest; used for crushing and grinding

Distinguishing among primate dentition:

- The different classifications of primates can differ in dentition formula, teeth shape and size, and jaw shape and size. Consider the following:
  - The lower jaw of apes and humans has a rounded angle. The lower jaw of other primates generally has a sharper angle.
  - Human premolars are called bicuspids because they have two cusps, or points. Ape premolars have only one cusp, which is useful for sharpening canines. Also, the front teeth of apes are generally larger than the back teeth, while in humans, the back teeth are generally larger than the front.
  - Canines in apes are pronounced, while in humans they are blunt and reduced. These large canines are more associated with display behaviors (e.g. showing off the large canine teeth to intimidate others) than with diet.
  - A dental comb is a special adaptation seen in many prosimians. The front teeth of the lower jaw point forward together to form the dental comb, which is used for grooming.

To calculate dental formula: Draw a vertical line down the front half of the teeth (in between the front incisors), then draw a horizontal line between the upper and lower jaw. This should divide the teeth into equal-sized quadrants. Note that each half of the jaw is symmetrical. The two halves of the upper jaw are identical to each other, and the two halves of the lower jaw are identical to each other. However, the upper and lower jaws may differ. Therefore, to properly record a dental formula, follow the instructions on the next page:

Name____ **Date** ____________

1. Choose a quadrant on the upper jaw. Count the total of incisors, then canines, then premolars, then molars. Represent this information in the following format: **Upper Jaw = # of Incisors . # of Canines . # of Premolars . # of Molars**

2. Now repeat this count for a quadrant of the lower jaw:

   Lower Jaw = # of Incisors . # of Canines . # of Premolars . # of Molars

   If, for example, you count the following:

   Upper Jaw = 2I. 1C. 2P. 3M / **Lower Jaw = 1I. 1C. 2P. 3M**

   Then you represent the dental formula like this: **2.1.2.3 / 1.1.2.3**

3. To calculate the total number of teeth, add all of the digits of the dental formula (for both upper and lower jaws). Then multiply by two, in order to include the remaining two quadrants.

   (2+1+2+3+1+1+2+3) x 2 = 30 (total number of teeth)

   General primate dental formulae

Primate	General Dental Formula
Prosimian	2.1.3.3 / 2.1.3.3
New World Monkey	2.1.3.3 / 2.1.3.3
Old World Monkey	2.1.2.3 / 2.1.2.3
Ape	2.1.2.3 / 2.1.2.3
Human	2.1.2.3 / 2.1.2.3

Teeth and Diet:
Primates are not specialized eaters, but do generally eat one type of food more often than another. Therefore, we can deduce information about a primate's diet by examining the size and shape of the different teeth types. Consider these general observations:

General Relationships between Teeth and Diet

Diet Type	Foods	General Dental Characteristics	Purpose of Dentition
Frugivore	fruits	large, wide incisors, sharp canines, low molars	piercing and peeling fruit; pulping and mashing fruit
Folivore	leaves	large, broad molars	grinding plants
Insectivore	insects	sharp teeth with pointed crests	seizing, piercing, and crushing hard-bodied insects

Name ____ **Date** ____________

Directions: For each picture below, determine and record the dental formula and total number of teeth to the best of your ability. Then, using all of the information you have learned about primate dentition and diet, try to correctly match each picture by letter to its primate classification. This may be challenging due to the condition of some of the jaws used in the photos!

Classification: a.) Prosimian, b.) New World Monkey, c.) Old World Monkey, d.) Ape, e.) Human

1.

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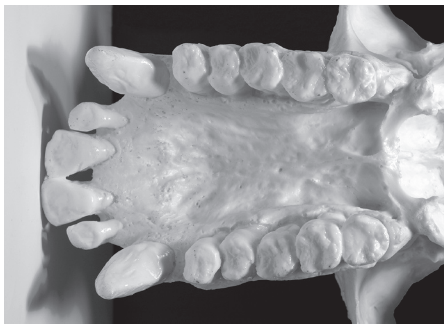
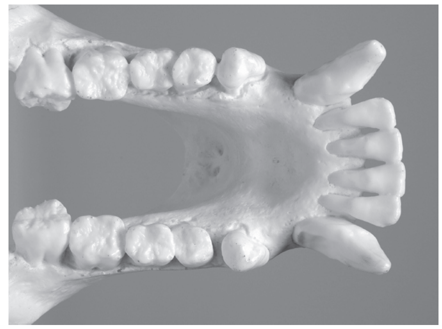


Upper jaw



Lower jaw

Dental formula: ______________________________

Total # of teeth: ______________________________

Classification: ______________________________

2.

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Right side

Left side

Dental formula: ______________________________

Total # of teeth: ______________________________

Classification: ______________________________

3.

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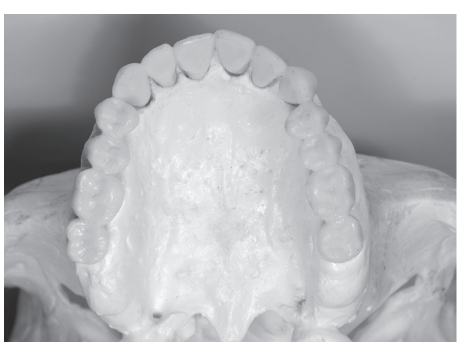

Upper jaw

Lower jaw

Dental formula: ______________________________

Total # of teeth: ______________________________

Classification: ______________________________

4.

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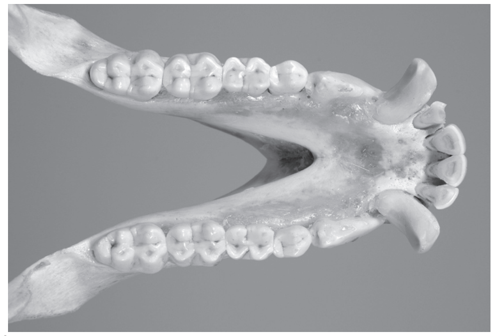
Upper jaw



Lower jaw

Dental formula: ______________________________

Total # of teeth: ______________________________

Classification: ______________________________

5.

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Front view

Side view

Dental formula: ______________________________

Total # of teeth: ______________________________

Classification: ______________________________

Note: The model human jaw used in this activity has the third molars (wisdom teeth) removed.

a. What diet might #1 have? Site your evidence.

b. What diet might #2 have? Site your evidence.

c. What diet might #4 have? Site your evidence.

3.3: How do scientists measure cranial capacity? **(C, M, S)**

Materials: Per student group: copies of "How do we measure cranial capacity?" worksheet, pencil, one mammal skull OR one emptied chicken egg (see below), string and ruler OR measuring tape, calculator, several cotton balls, tape, graduated cylinder, and pack of millet, sand, or salt (these materials are ideal because they approach the volume equivalent of a liquid).

Objective: The student will be able to experiment with laboratory methodology, and compare and judge the accuracy of attempted procedures in order to experience the process of scientific development and revision of methods.

Procedure:

- Break students into pairs (or larger groups if you have fewer skulls/eggs). Give each group the materials listed above.
- Before they work on the task, discuss why scientists might measure cranial capacity. What information can be obtained? Remember to emphasize that:
  1. Cranial capacity is a measure of the volume of the interior of the cranium or braincase
  2. Only vertebrates have a cranium
  3. Cranial capacity is an indicator of the size of the brain
  4. A large brain in relation to body size is associated with higher intelligence and behavioral complexity when comparing species to species. It is not a valid indicator of intelligence levels within a species.
- In their groups, students should now review their worksheets. Worksheet parts one through two ask them to think of up to three methods for measuring the cranial capacity of their specimen. They should test and record these methods in worksheet part two.
- The goal is for students to deduce a method for measuring volume. They might start by measuring the outside of the skull/egg using the measuring tape or string and ruler. They might also try to apply standard volume formulae. (You may supply them with some standard formulae including: Volume of a cube = side^3; Volume of a sphere=(4/3) * pi * radius^3).
- You can assist students by encouraging their ideas and providing feedback on the relative merits of their ideas. Allow students to record their results on their worksheets noting the measurement units they use.
- If they do not come to this method on their own, you may eventually demonstrate to students this common method used in laboratories (if using egg models, hold one finger under the small hole to stop spillage, and consider the larger hole an equivalent to the foramen magnum; then follow steps three to five):
  1. Stuff the openings of the skull with cotton (tape cotton in place if necessary)
  2. Do not stuff the *foramen magnum*! This hole, where the spine attaches, will be used to fill the cranium
  3. Turn the skull over and place the funnel in the *foramen magnum*. Using the funnel and the millet (or similar material), carefully fill the cranium to capacity, agitating the millet to assure the most accurate measurement.
  4. Transfer the millet from the cranium into the graduate cylinder, and note the measure (in cubic centimeters).
  5. Repeat this process and report an average volume.
- Now students may compare the results of their methods, including the technique described above, to the actual data (you should obtain this based on your chosen mammal, or by measuring a test egg yourself before class starts). Here are two resources for obtaining cranial capacity data:

  Comparative Mammalian Brain Collections: http://brainmuseum.org/
  Neuroscience for Kids: http://staff.washington.edu/chudler/neurok.html

- Discuss the exercise with your students. Was it difficult for them to find a methodology that gave them an answer similar to the actual data? Ask them to explain their thought processes and lines of reasoning while they were developing their methodologies.

Assessment Criteria: The student works in a group to deduce methodology given the task and a variety of material, test the methodology, and judge its relative merits against actual data. The student is open to revision in the scientific process.

Extension: Compare the cranial capacity of your students' test specimens to the data on ape cranial capacity below. What information can you deduce about comparative intelligence and behavioral complexity? How might students explain the range within any one species as reported below?

Orangutans	275-500cc
Chimpanzees	275-500cc
Gorillas	340-750cc
Humans	1100-1700cc

Tips:

- To use a chicken egg, puncture a small hole in one end of the egg and a slightly larger hole in the other end. Blow the contents out by blowing steadily into the small hole until all the contents exit through the larger hole.
- Opossum, cat, and rodent skulls can be obtained at any commercial biological supply company, such as Carolina Biological Supply Company or Acorn Naturalists. You can also contact museums, university research departments, or local game authorities for donation of materials.

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Red-ruffed lemur skull

Skills used in this activity

- Designing and conducting scientific investigations
- Collaborative inquiry
- Revising and ranking lab methodology

Name ______________________________ **Date** __________

Worksheet: How do scientists measure cranial capacity?

1. What can we learn about an animal by measuring cranial capacity? What other information might we need to know in order to understand the meaning of an animal's cranial capacity?

2. Using any combination of the materials provided to you, deduce up to three methods for measuring the cranial capacity of your specimen. Briefly describe each method and the measuring unit used:

3. Test your methods. Reserve the fourth row for the method demonstrated by your instructor. This may or may not be the same as one of the methods you designed.

Method	Measurement (include unit)
1.	
2.	
3.	
4.	

4. Compare your findings to the actual data reported by your instructor. Which was the most accurate method? Why?

Thinking Ahead

In order to begin the process of connecting physical phenomena with behavioral phenomena, discuss the following with your students:

How might an ape's physical characteristics relate to its behavior?

Consider, for example, the shape of an ape's teeth, its body shape, and the size of its brain.