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MALE-FEMALE DIMORPHISM IN HOMINIDS

Instructor Curriculum

Male-Female Dimorphism in Hominids

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Authors:

Valentina González Torres

Chris N. Bayer, PhD

Peer reviewers:

Molly Selba, PhD

ABSTRACT

Bonobos and chimpanzees are our closest living relatives. While most people know about chimps, few know about bonobos. Isolated from other apes by the giant Congo River, bonobos have evolved a social system that is unique among non-human primates: by forming coalitions females create a dominant order, males maintain a lifelong bond with their mother, and male on female physical aggression is buffered.

This "Male-Female Dimorphism in Hominids" lab has students compare and contrast these three great ape species: bonobo, chimp and human. Students investigate the interplay between: (1) sexual dimorphism — by measuring 3D-printed skulls, and (2) behavioral traits — by conducting ethograms. Juxtaposing physical and behavioral traits within each species, students learn that physical and behavioral traits are correlated: the male chimp's more pronounced brow ridge, jaw, and canine teeth are correlated with their male-dominated social structures where males compete for females and keep harems.

Humans and bonobos exhibit less sexual dimorphism than chimps. The likely explanation of this fact is that humans and bonobos have undergone a process of self-domestication – a phenomenon in which a species evolves to become more docile, less aggressive, and more cooperative with other individuals in their own species over time.

This lab serves as an example of how behavior, collectively practiced in the form of culture, may in turn impact the genotype level through so-called Baldwin effects ("behavior as selection pressure"). Self-domestication in bonobos has, in turn, shaped the very morphology of the species and lessened its sexual dimorphism.

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LAB SPECIFICATIONS

Objective

The goal of this lab is to provide students with an authentic scientific experience in which they examine anatomical and behavioral similarities and differences between our species and our two most closely related ape relatives, the chimp and the bonobo. Having shared a common ancestor 7 million years ago, distinct physical and behavioral traits reveal the significant impact of evolutionary changes over time.

Upon being tasked with conducting a 3D skull-based investigation, students conduct an ethogram drawing on audio-visual material. Juxtaposing sexual dimorphism with basic social behaviors, students unpack the interaction between phenotype and genotype traits, revealing morphologic trends and feedback loops between physical and behavioral traits in the species.

Inquiry-Based Pedagogy

A key aspect of inquiry-based pedagogy is promoting students to think beyond provided information. This lab features a scientific investigation in which, upon having presented sufficient background information, students are prompted to adopt a scientist's mindset, analyze the collected data, and discuss the merits of leading hypotheses. The teacher's role in these activities is to facilitate student learning rather than impose information on the student. Thus, this lesson is less lecture-and-demonstration or textbook-based and rather learning by doing.

Timeframe

This lab can be completed within 3 to 4 hours, depending on the time limits set by the teacher.

Target Audience

This resource is intended for high school biology teachers, equipping them to deliver this lab to high school biology students.

Prerequisite Knowledge

It would be helpful if students already understood the basic tenets of evolution (the interplay between genetic mutation providing the diversity from which natural selection selects).

Lesson Plan Format

All lessons in this curriculum unit are formatted in the same manner, and all related materials, e.g. lesson plans and handouts, are provided. In each lesson you will find the following components:

Student learning objectives

Focuses on what students will know, feel, or be able to do at the conclusion of the lesson.

Materials

Items needed to complete the lesson.

Procedure and discussion questions with time estimates

The procedure details the steps of implementation with suggested time estimates. The times will likely vary depending on the class.

Background information

Essential information given to students at the start of every lesson.

Data collection

Explanations and steps for gathering the required data to complete the task.

Data analysis & interpretation

The students' collected data is then analyzed, and basic connections are made to derive meaningful insights.

Discussion questions

Additional questions that may assist students in reaching conclusions. To be used only if needed.

Student handouts

Worksheets to be copied and distributed.

Answer key

Versions of the student hand-outs with answers.

Notes

Essential explanations or clarifications required by the instructor to ensure the smooth execution of the laboratory.

LESSON 1

Anatomical Assessment

Student Learning Objectives

- Define sexual dimorphism.
- Explore how sexual dimorphism manifests in physical characteristics between males and females of chimpanzees, bonobos, and humans.
- Examine the extent of sexual dimorphism in chimpanzees, bonobos, and humans.
- Compare and contrast the patterns of sexual dimorphism observed in each species.
- Explore the interplay between environmental influences in driving sexual dimorphism.

Materials

- 3D-printed skull set;
- Powerpoint Presentation;
- Measuring devices: (1) sliding caliper, (2) mustard seeds, beaker or spoon, funnel and flask;
- Student Handouts (A, B); & Answer Keys

Procedure and Time Estimates

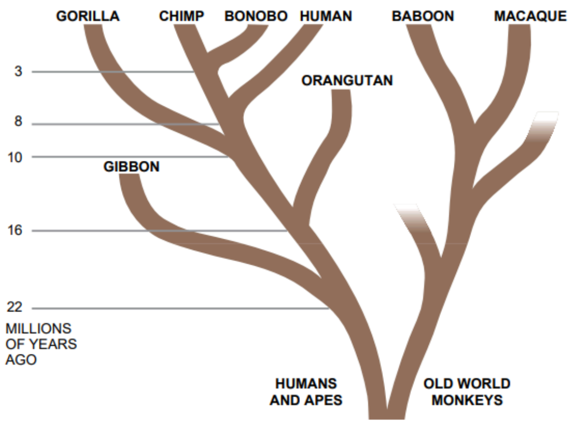
Activities	Background information for the class	Data collection	Data Analysis & Interpretation	Time Estimates (aprox)
Intro lecture	X			(10-15 min)
First set of measurements		X		(5-7 min)
Second set of measurements		X		(5-7 min)
Third set of measurements		X		(5-7 min)
Data analysis			X	(7-10 min)
Data interpretation			X	(15-20 min)

Background Information

Speciation

Chimpanzees and bonobos are our closest living surviving relatives in the animal kingdom. At some point between 6 and 7 million years, one ape species split into two groups: humans emerged from one group, and chimpanzees and bonobos evolved from the other. It was between 1 to 2 million years ago that this latter group separated into bonobo and chips (Figure 1).

Figure 1 - Evolutionary tree of primates



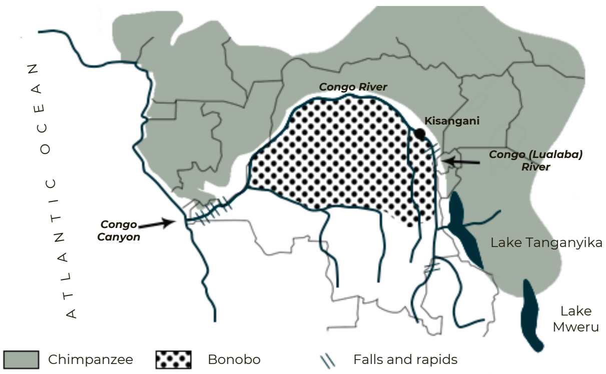
Note. Figure 1. Evolutionary tree of primates. In Bonobo Sex and Society, (p. 84); by F. de Waal, 1995, New York, NY:Scientific American, Inc..

Today, chimps are found in western and central Africa, while bonobos are exclusively found in the Democratic Republic of the Congo (Figure 2).Separating the two species is the Congo River (Figure 3),which is the third largest river in the world by discharge volume (averaging 41,000 m3/s),and the world's deepest recorded river (around 219.5 m/720 ft).

So, how did bonobos arrive on the south side of this massive barrier? Well, scientists reason that at one point between 1 to 2 million years ago, the river's flow dropped significantly, making

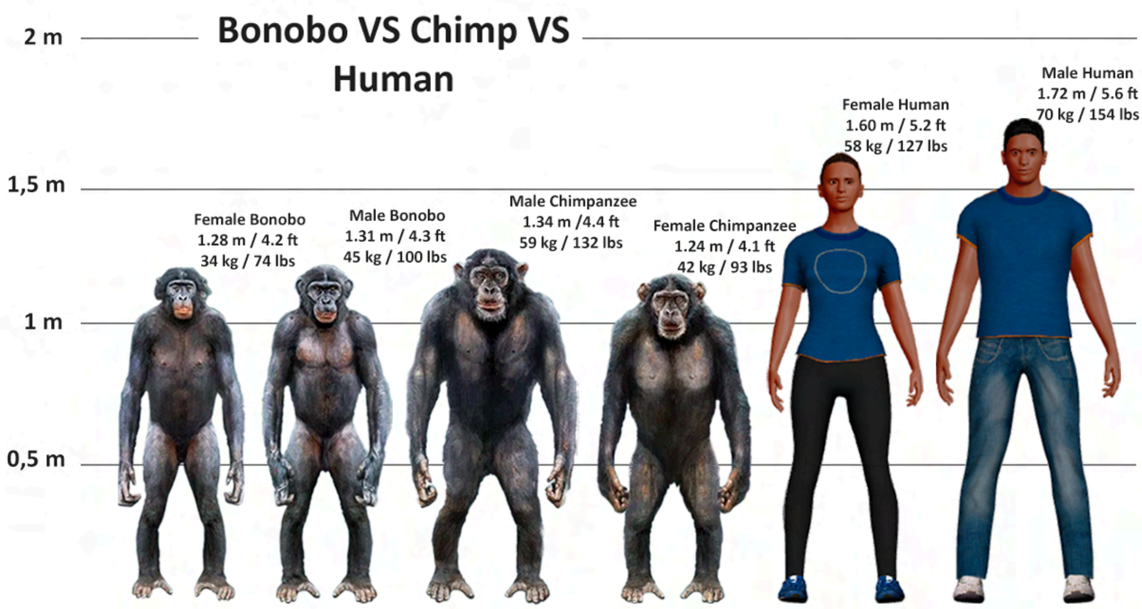
Figure 2 - Satellite image of Africa

Figure 3 - Congo River



it possible for a group of apes to make their way to the other side, which marked the time when the population split in two (Takemoto et al. 2015). Scientists call such an event 'allopatric speciation'. Interestingly, while to this day chimpanzees typically steer clear of the river, bonobos occasionally enter the water up to their waist to forage, even though they cannot swim.

Figure 4 - Comparison in height and size between bonobos, chimpanzees and humans of both sexes



Since that journey across the river, bonobos and chimps have retained some features but also exhibit divergent physical and behavioral characteristics. In both, their hair is black, and neither have tails (unlike monkeys). While bonobos have a smaller stature and more slender shape, they can stand more upright than chips (Frans de Waal, 1995).

Both chimps and bonobos are around two-thirds the size of humans, as is illustrated in Figure 4. Nevertheless, all three ape species share about 98.7% of their DNA (Gruber, T., & Clay, Z., 2016).

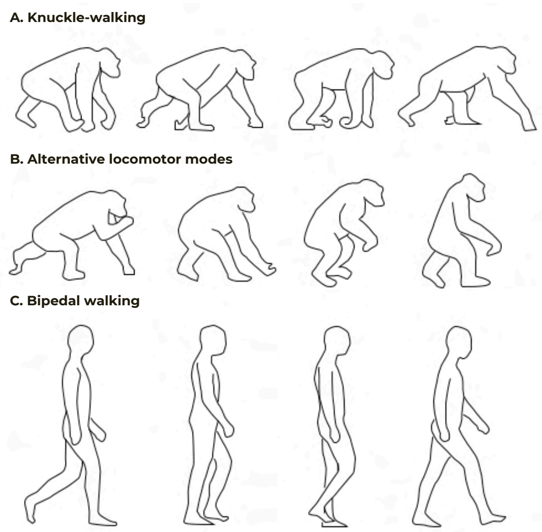
Walking habits

Chimpanzees primarily use a mode of walking known as knuckle-walking (they move on their knuckles with their fingers curled under). And while they can spend a significant amount of time on the ground, they are also adept climbers. But their bipedal walking is less smooth and efficient compared to humans.

Chimpanzees can walk on two legs for short distances, especially when carrying objects or reaching for fruits on low-hanging branches.

Bonobos also engage in knuckle-walking, but they are more frequently observed walking upright on two legs, especially when carrying food or wading through water. Similar to chimpanzees, bonobos are capable climbers and spend time both on the ground and in trees.

Figure 5 - Locomotion



Humans, on the other hand, are characterized by habitual and efficient bipedal walking. The skeletal structure, particularly the development of the spine and pelvis, supports upright posture and efficient walking on two legs.

Feeding habits

In general, chimps are omnivorous. They mainly feed on fruits and leaves but are also known to eat insects (termites, grubs, and worms). Male chimps organize hunting parties, eat meat and share it with females, and while sometimes they may kill a large vertebrate (juvenile bushbuck), they prefer to target smaller animals.

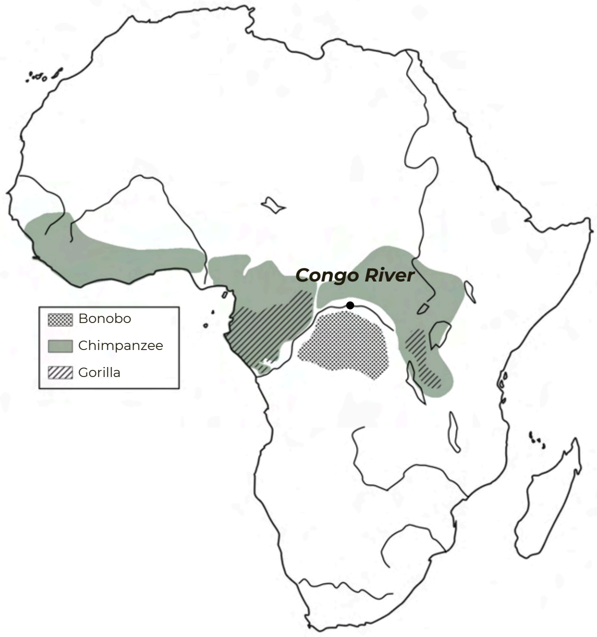
Bonobos, like chimpanzees, have a wide-ranging diet that includes leaves, insects, and fruits. Yet they have also been observed to consume meat in rare instances: for example flying squirrels, duikers, and bats. But unlike their cousins, they also like to venture into swamps, pools, and streams to feed on aquatic fungi (such as truffles), dragonfly larvae and earthworms (Terada, 2019).

Keep in mind that chimpanzees share their territory with gorillas (Figure 6), which means competing with those bigger apes for food and other resources; a problem that bonobos do not face in their neck of the woods.

Humans consume a diverse range of foods: this omnivorous diet allows for a more balanced intake of nutrients, with options for both plant-based and animal-derived sources of protein, vitamins, and minerals.

Also, way humans prepare and cook their foods, sets us apart. While other animals consume primarily raw and unprocessed foods in their natural state, humans have harnessed the power of fire and cooking techniques to transform their diets. Cooking not only enhances the taste and texture of certain foods, it also aids in breaking down certain compounds, making nutrients more readily available for absorption.

Figure 6 - Bonobo & Chimpanzee Location

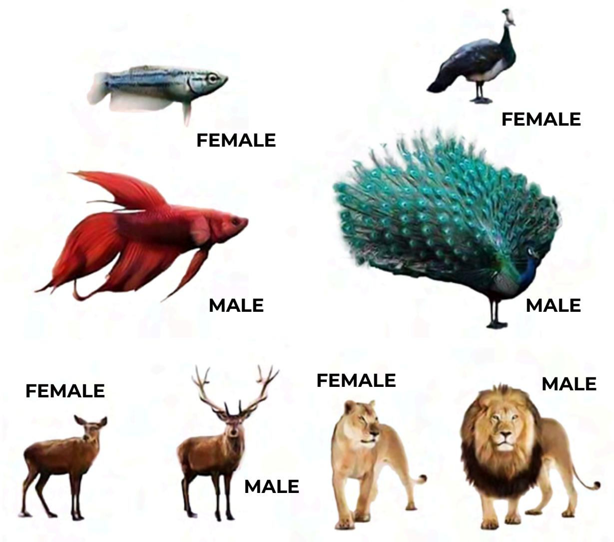


Sexual dimorphism

The term "sexual dimorphism" can be used to describe any difference between males and females of the same species. These differences can include things such as size, shape, coloration, and body features. For example, in many species, males and females may look different, with one being larger or having special traits such as colorful feathers or antlers (Figure 7).

Biologists recognize that there are primary and secondary sex characteristics: primary sexual characteristics are the physical traits,

Figure 7 - Examples of female & male within a species.



namely your reproductive organs, that you are born with that determine whether you are male, female, or some sort of combination (intersex). Secondary sexual characteristics are physical traits that develop as you go through puberty and grow into an adult.

Dimorphic traits further include height, weight, and body shape. For example, the average female bonobo size is 82.5% that of the male. Yet, sexual dimorphism can also be observed in behaviors. For instance, in many bird species, males engage in elaborate courtship displays, while females build nests and care for offspring.

Sexual dimorphism is present when certain traits are more prevalent as they e.g. provide advantages in attracting — or competing for access to — mates. This can lead to the evolution of exaggerated and elaborate traits in one sex, such as the antlers of male deer. But the degree and nature of sexual dimorphism varies across species, and not all species are dimorphic.

What is a skull replica?

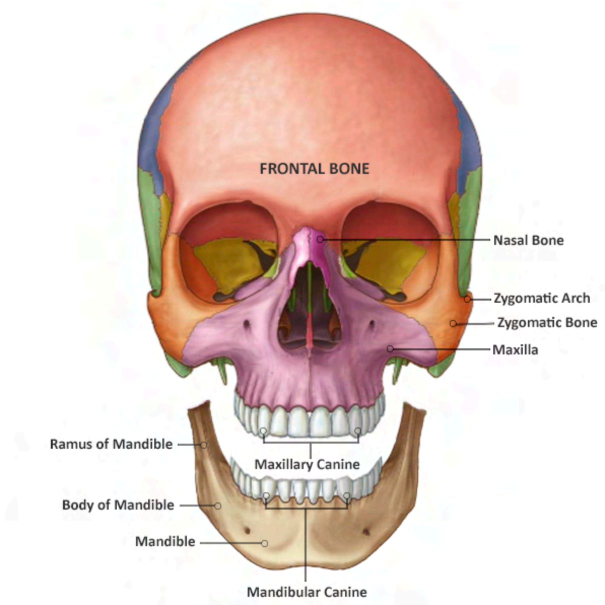
A skull replica is a copy of the original skull made either through: careful casting techniques in which a mold is made from the original skull, followed by a cast being made from that mold, or utilizing 3D scanning and printing technology (3D computer model & a 3D printer).

Basic components of a skull

General terminology:

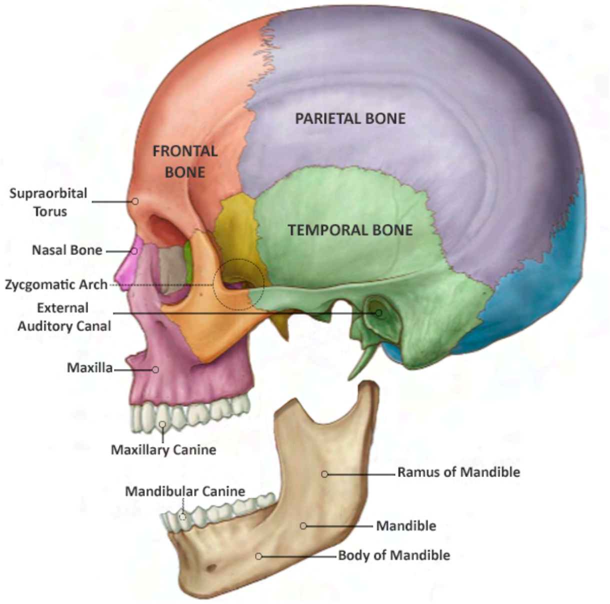
Skull: the head, face, and lower jaw or mandible (see Figure 8).
Cranium: skull lacking its lower jaw or mandible.
Braincase: includes the frontal bone, the occipital bone, the temporal and parietal bones (see Figures 8, 9, 10, 11, 12). Calvaria: is the top part of the skull (superior portions of the frontal bone, occipital bone, and parietal bones). Facial bones: include the mandible, the maxilla, the brow ridge, the nasal bones, the zygomatic bones, etc (see Figure 8).

Figure 8 - Anterior view of the Skull



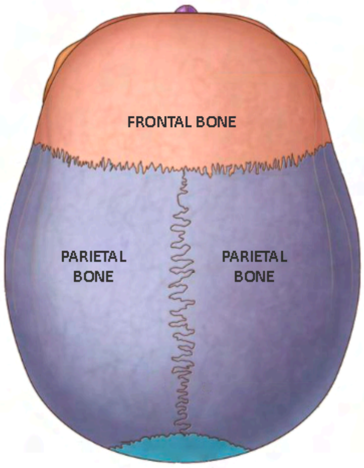
Note. Figure 8. Anterior view of the Skull. In Gray's Anatomy for Students. Fourth Edition, (p 843), by R. Tibbitts & P. Richarson, 2020, Philadelphia, PA: Elsevier Inc.

Figure 9 - Lateral view of the Skull



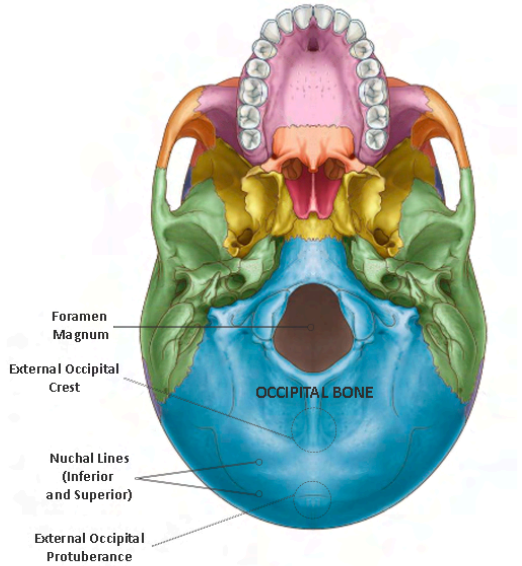
Note. Figure 9. Lateral view of the Skull. In Gray's Anatomy for Students. Fourth Edition, (p 845), by R. Tibbitts & P. Richarson, 2020, Philadelphia, PA: Elsevier Inc.

Figure 10 - Superior view of the Skull



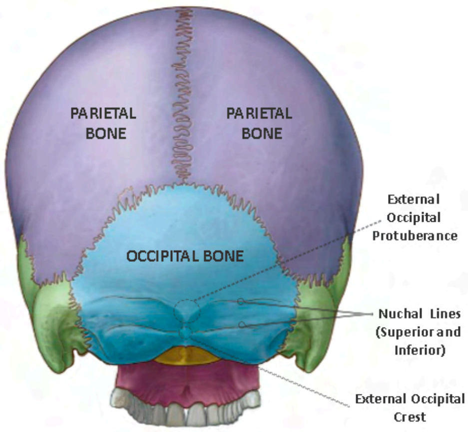
Note. Figure 10. Superior view of the Skull. In Gray's Anatomy for Students. Fourth Edition, (p 848), by R. Tibbitts & P. Richarson, 2020, Philadelphia, PA: Elsevier Inc.

Figure 11 - Inferior view of the Skull



Note. Figure 11. Inferior view of the Skull. In Gray's Anatomy for Students. Fourth Edition, (p 850), by R. Tibbitts & P. Richarson, 2020, Philadelphia, PA: Elsevier Inc.

Figure 12 - Posterior view of the Cranium



Note. Figure 12. Posterior view of the Skull. In Gray's Anatomy for Students. Fourth Edition, (p 847), by R. Tibbitts & P. Richarson, 2020, Philadelphia, PA: Elsevier Inc.

What is the difference between sex and gender?

Sex is typically assigned at birth based on physical characteristics, whereas gender identity is how individuals perceive themselves.

What is an ape?

An ape is a member of the primate family characterized by the absence of a tail, distinguishing them from most monkeys. Apes are generally larger, more intelligent, and their societies are more socially complex than monkeys. Chimpanzees, gorillas, orangutans, bonobos, and humans are so-called *great apes* (Hominidae).

Data Collection

In this lesson, the students research the similarities and differences in anatomy between humans, chimpanzees and bonobos, as well as the level of sexual dimorphism between the sexes of each species by measuring the skull and facial structures.

NOTE: Create three workstations (one for each species) for the students to rotate and maximize time.

Measurements and visual assessments

1. Overall size and appearance of the cranium:

Definition: The cranium is composed of bones and cartilage, which form a unit that protects the brain and sense organs. The lower jaw is not part of it.

Instrument: Senses of sight and touch.

Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Image 1 - Male chimpanzee & female chimpanzee

Step 1 - Arrange the craniums with their faces oriented upward.

Image 2 - Overall size and appearance of the cranium

Step 2- Focus on the size and shape.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Overall size and Appearance	Gracile (small, slender).	Slightly smaller, slim.	Moderate size, proportionate.	Slightly larger, more angular and wide.	Robust (large, rugged, wide or broad).

2. Facial prognathism

Definition: A prognathic face protrudes forward from the braincase, while an orthognathic face lies almost entirely beneath the braincase.

Instrument: Senses of sight and/or touch.

Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Figure 13 - Prognathic & Orthonathic faces

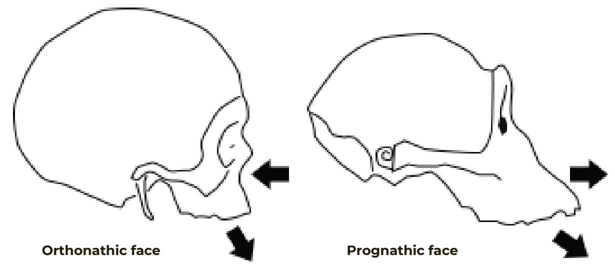


Figure 14 - Foramen magnum

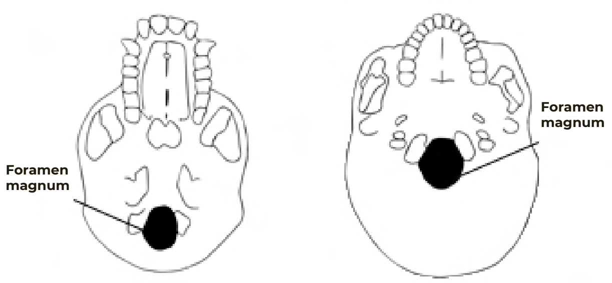
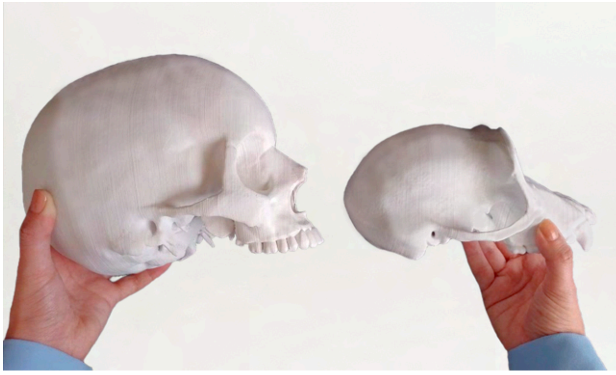
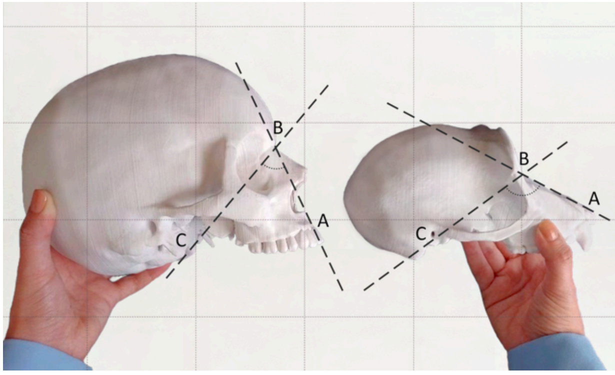


Image 3 - Male human & male chimpanzee



Step 1 - Arrange the skulls in a way that their sides are oriented upward.

Image 4 - Facial prognathism



Step 2 - Identify the most anterior points on the maxilla (A), nasal bone (B), and foramen magnum (C), and roughly connect these three points to create an angle. An acute angle suggests an orthognathic face, while a more obtuse angle indicates a prognathic face.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Facial prognathism	Short and retracted face.	Slightly shorter	Moderate	Slightly extended and protruding	Long and projecting face.

3. Zygomatic Arches

Definition: The zygomatic arches, part of the cheekbone, connect the zygomatic bone with the temporal bone. They also provide a gap for the temporalis muscles to pass through (muscles involved in generating bite force).

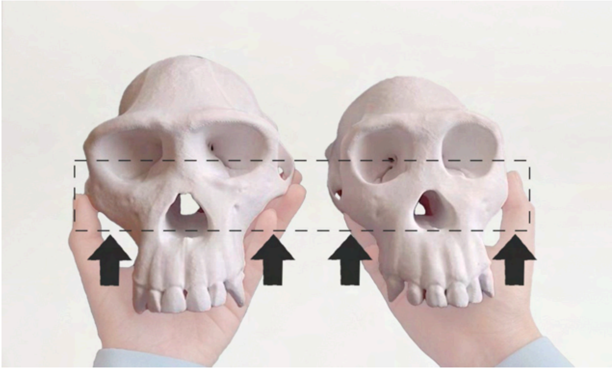
Instrument: Senses of sight and/or touch.

Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Image 5 - Male chimpanzee & female chimpanzee

Step 1 - Arrange the craniums with their faces oriented upward.

Image 6 - Zygomatic arches (anterior view)

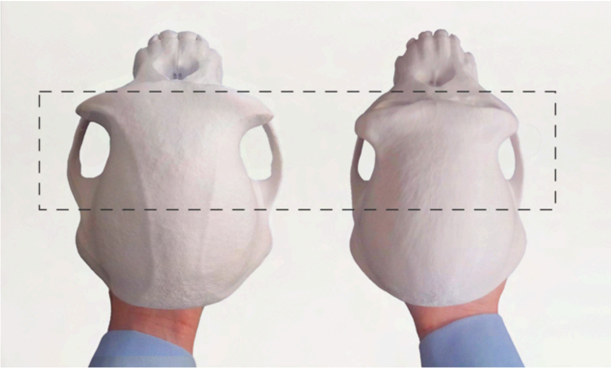


Step 2 - Locate the zygomatic arches and observe their dimensions.

Image 7 - Male chimpanzee & female chimpanzee

Step 3 - Place the cranium in a way that its superior view is facing you.

Image 8 - Zygomatic arches (lateral view)



Step 4 - Find the zygomatic arches and observe their dimensions. To assist you, you can use the external auditory canal as a point of reference.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Zygomatic arches	Does not extend past the external auditory canal.	Barely extends past the external auditory canal.	Moderate.	Extends past the external auditory canal.	Extends far past the external auditory canal.

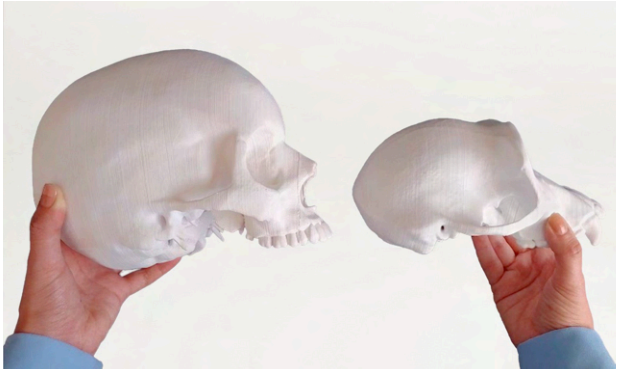
4. Brow ridge or supraorbital torus

Definition: This is a bony ridge located above the eye sockets.

Instrument: Senses of sight and/or touch.

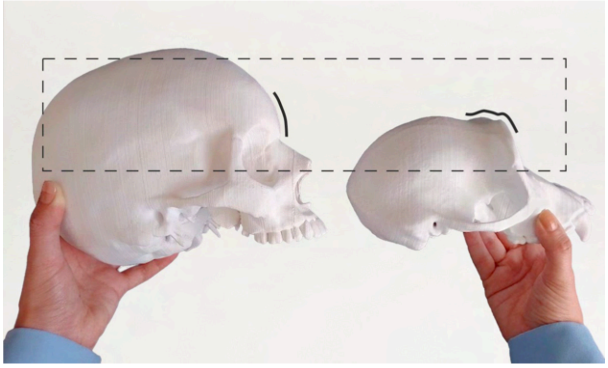
Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Image 9 - Male human & male chimpanzee



Step 1 - Arrange the skulls in a way that their sides are oriented upward.

Image 10 - Supraorbital torus (lateral view)

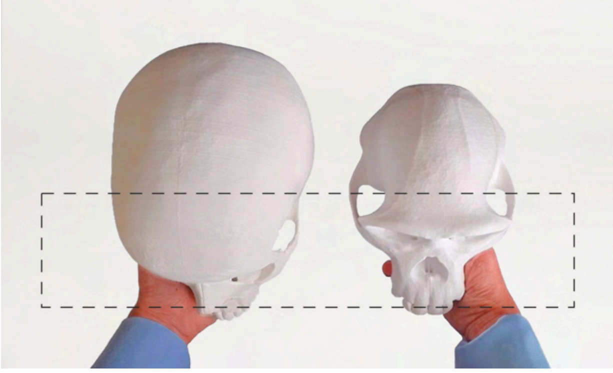


Step 2 - Locate the supraorbital torus and examine its size and shape.

Image 11 - Male human & male chimpanzee

Step 3 - Place the cranium in a way that its superior view is facing you.

Image 12 - Supraorbital torus (superior view)



Step 4 - Locate the supraorbital torus and examine its size and shape.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Supraorbital torus	Smooth	Slightly delimited	Delimited	Marked	Massive and prominent.

5. Nuchal Area

Definition: This is the area where the neck muscles attach to the back of the skull.

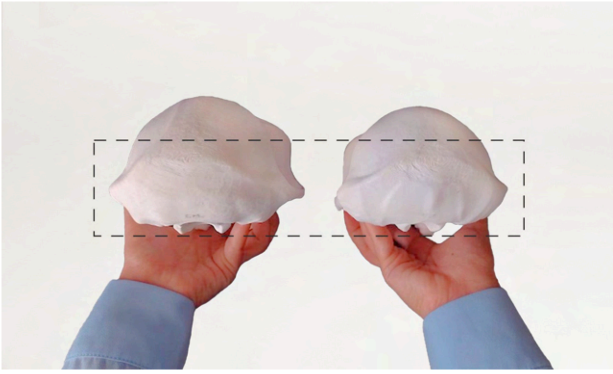
Instrument: Senses of sight and/or touch.

Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Image 13- Male chimpanzee & female chimpanzee

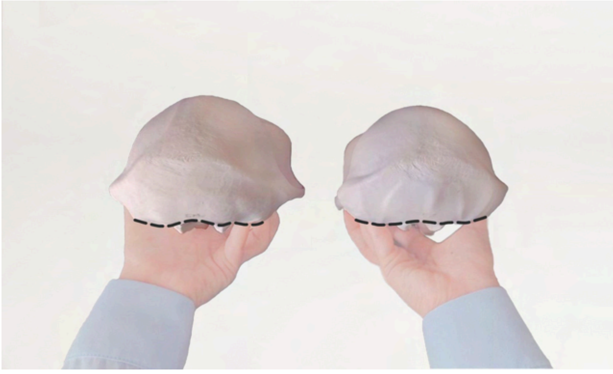
Step 1 - Arrange the skulls in a way that their backs are oriented upward.

Image 14 - Nuchal Area (posterior view)



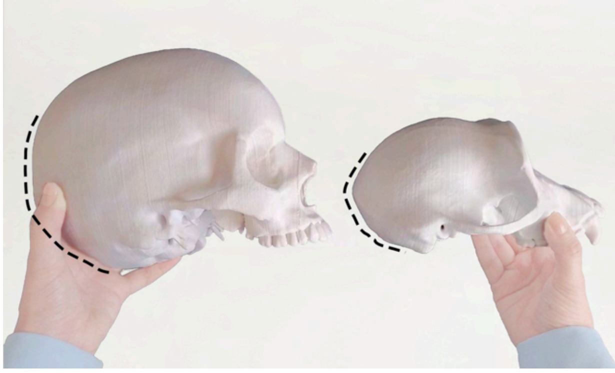
Step 2 - Locate the nuchal lines and occipital crest torus and examine its size and shape.

Image 15- Nuchal Area (posterior view)



Step 3 - Use the baseline of the skull as a reference

Image 16- Nuchal Area (lateral view)



Step 4 - To achieve greater precision, arrange the skulls with their sides facing upward and focus on the curvature of the cranium's rear shape.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Nuchal Area	Smooth	Slightly arched, traces of nuchal lines.	Nuchal lines and occipital crest evident.	Nuchal lines and occipital crest marked.	Nuchal lines and occipital crest with rough surface.

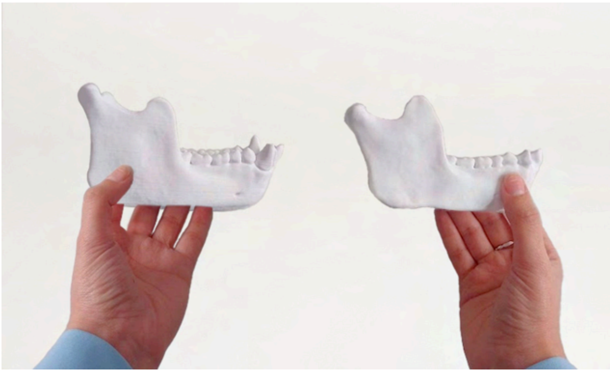
6. Mandible

Definition: the mandible (lower jaw or jawbone) is the bottom skeleton that makes up the lower half of the mouth.

Instrument: Senses of sight and/or touch.

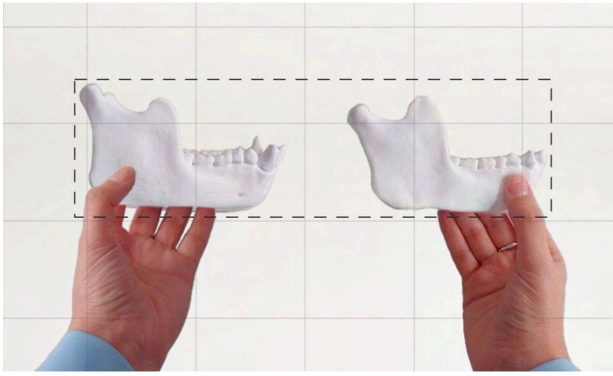
Method: After a thorough visual and/or tactile inspection of each skull, score the trait according to the scale below.

Image 17- Male chimpanzee & female chimpanzee



Step 1 - Arrange the mandibles in a way that their sides are oriented upward.

Image 18 - Mandible (lateral view)



Step 2 - Locate the different components of the mandible and meticulously examine its size.

Trait	Description				
	(-2)	(-1)	(0)	(+1)	(+2)
Mandible	Small, narrow ascending ramus.	Reduced size, thinner structure.	Medium	Prominent jawline but less robust.	Large, robust, wide ascending ramus.

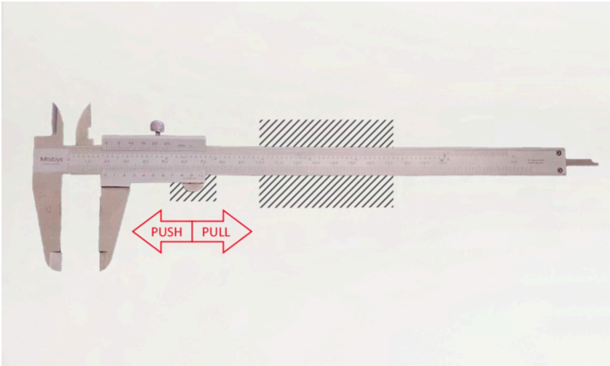
7. Maxillary and Mandibular canines

Definition: The maxillary canines are found in between the maxillary incisors and the premolars and they erupt from the upper gums. While the mandibular canines are found on the lower jaw and also between the incisors and the premolars.

Instrument: Sliding caliper.

Method: Canine height is measured from the base of the tooth to the apex. Place the mandible or the cranium on its side and place the end of the fixed crossbar against the base of one of the canines. To take the measurement, slide the crossbar that can be moved to the apex (pointy end). Once you have obtained the measurement, record it. To ensure accuracy, double-check your measurement by reopening the caliper jaws and re-measuring the object. Double checking would confirm that you have obtained an accurate measurement.

Image 19- Sliding caliper



Step 1 - Place your hand in such a way that you can hold the caliper by its main body, leaving your thumb free to place it on the small elevation on the slide or thumb grip. To facilitate the opening and closing of the crossbars, simply exert force with your thumb, making use of the grip as a support.

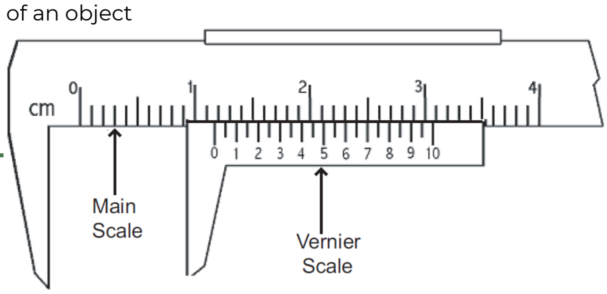
Image 20 - Mandibular canine (lateral view)

Step 2 - To measure the mandibular or maxillary canine, use your free hand to hold the jaw or cranium so that its side is oriented upward and positioned perpendicularly to the caliper.

Image 21- Mandibular canine & sliding caliper

Step 3 - Place the end of the fixed crossbar against the base of one of the canines and slide the crossbar that can be moved to the apex of the canine (pointy end). Carefully read the scale or dial on the caliper to determine the measurement.

Figure 15 - Vernier caliper for measuring the external size of an object



Note. Figure 15. Vernier caliper for measuring the external size of an object. In College Physics Labs - Mechanics. Second Edition, (Appendix D), by NC State University Physics Department, 2010, North Carolina, PA: Advanced Instructional Systems, Inc.

To measure the width, you read the top and bottom scale as follows:
Find where the 0 mark of the vernier scale lines up on the main scale. In this case, it is between 11 and 12 mm. So, the first reading is 11 mm.
Now find the mark on the vernier scale that most closely lines up with one of the marks on the main scale. Here, 6.5 lines up best with one of the marks on the main scale. This value is the number of tenths of millimeters. So, the second reading is 0.65 mm.
Add the two values together to get the total reading: 11 mm + 0.65 mm = 11.65 mm.
For more information, see this Wikipedia entry.

Trait	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Mandibular canine (mm)						
Maxillary canine (mm)						

8. Cranial capacity

Definition: It is the volume of the braincase or the cranium (a proxy for brain size).

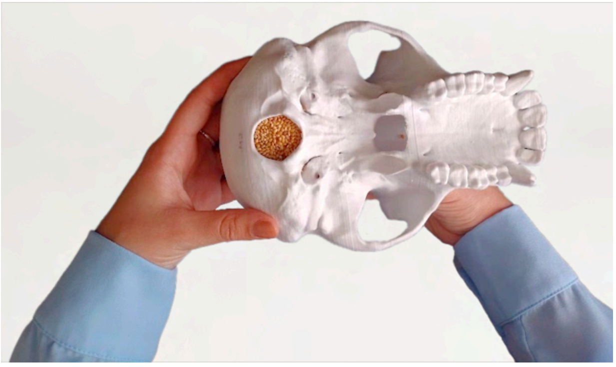
Instrument: Mustard seeds, beaker or spoon, flask and a funnel.

Method: The cranium is filled with mustard seeds, tilted to distribute them throughout, tapped twice to settle its contents, and then filled to the plane of the foramen magnum rim. The seed is then poured into a flask and recorded to the nearest cm3. The measurement is performed three times, and the mean is taken.

Image 22 - Male chimpanzee & mustard seeds

Step 1 - Locate the foramen magnum and grasp the cranium with it oriented upward.

Image 23 - Filled male chimpanzee cranium



Step 2- Step 2- Fill the cranium with mustard seeds through the foramen magnum. To make things easier, you can utilize a funnel or a spoon.

Image 24 - Flask

Step 3- Once filled to the brim, pour the contents into a jar and measure to the last cm3. To make things easierTo help you, you can use the a funnel.

Trait	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Cranial capacity (cm3)						

Data Analysis

NOTE: Form student work groups to work collectively and discuss.

Comparative analysis between the species

Human face bones differ significantly from those of its nearest surviving cousins in the genus Pan. Chimpanzees, like other contemporary apes, are marked by strong supraorbital tori and long projecting lower faces that house significantly bigger front teeth (incisors and canines).

Bonobos have a smaller skull, a shorter and broader face, a smaller jaw, and a much smaller dentition compared to chimpanzees. Bonobo individuals are most similar to humans in their dentition (see canine tooth).

Modern humans have much smaller front teeth and a midface that does not stick out in front. The canines look more like incisors. The modern human face and orbits are tucked under a brain that is substantially larger than that in Pan (or any other extant ape) and the supraorbital morphology is reduced.

Analysis of differences between the sexes

Chimpanzees, along with bonobos and humans, exhibit sexual dimorphism in skull characteristics.

Male chimpanzees tend to have larger and more robust skulls, with broader brow ridges, larger cranial vaults, and thicker jaw bones than females.

Bonobos males and females have a similar cranial structure and shape, with only slight differences in size. The two more noticeable points of distinction are that males tend to have bigger zygomatic arches, and in the back of the skull, the occipital crest tends to be more marked, creating a pointy surface to the touch.

In humans, the differences between male and female can be observed in the skull's overall size, as well as in specific features such as the supraorbital torus and mastoid size. On average, female individuals are smaller in cranial size and overall more gracile compared to males.

While the morphology of the supraorbital region is less robust, the superolateral margin of the orbit is thinner, the zygomatic bone is more delicate, the mastoid processes are smaller, and the top of the head is more rounded in human females. The opposite is true for males.

Each of the three species exhibits a degree of sexual dimorphism. However, compared to chimpanzees, the amount of sexual dimorphism in human and bonobo skulls is more modest. For example, in male chimpanzees, canine teeth are frequently larger and more prominent compared to females, while in bonobos and humans, the canine teeth are smaller and only slightly different between males and females.

Also, male chimpanzees tend to have larger and more robust skulls with broader brow ridges, larger cranial vaults, and thicker jawbones than females. While bonobos and humans, both males and females, are known for having a similar cranial structure and shape, with only slight differences in size.

All in all, while there are some male-female differences in human and bonobo features, they are typically more subtle than those seen in chimpanzees.

Data Interpretation

What accounts for the variation in size across the three species?

Observing their physical characteristics, we note that chimpanzees are larger in body size (skull) compared to bonobos. This variation can be attributed to the different environments they inhabit. Chimpanzees live in forests, woodlands, and savannas, where they need to climb trees and move quickly. Their relatively larger size helps them maneuver through the trees more easily. Bonobos, on the other hand, live in dense rainforests where they spend less time climbing and more time on the ground. Their slightly smaller size gives them an advantage in moving on the forest floor.

Humans, as a distinct species, have evolved unique characteristics and abilities. Compared to chimpanzees and bonobos, humans have a larger body size. One important factor is the evolutionary history as bipedal creatures (walking on two legs). Consistently walking upright ("obligate bipedalism") requires a different body structure and size compared to our primate relatives. Our larger size provides stability and balance while walking on two legs.

Additionally, humans' larger brain size has an influence on our body size. A larger body can support a larger brain and make it easier to acquire the associated energy requirements.

However, as we delve into the size variations, a second question draws our focus: why is there a difference in size between the sexes in each of three species? The measurements gathered in these instances indeed reveal a size distinction, even if it is minimal, as seen in the case of bonobos.

A size difference between the sexes is prevalent in numerous species, and to elucidate this, we must consider the involvement of genetic, hormonal, and evolutionary factors. However, our current focus is solely on underscoring that this size difference can manifest as a strategy to enhance the species' survival. In certain species, particularly those facing intense competition for resources, natural selection might favor the larger size of one gender, providing advantages in territorial disputes, securing food, or attracting mates.

Does the size of the brain relate to the size of the body? If the answer is yes, what effect does this have on intelligence?

In general, brain size increases with organism size: the larger the animal, the bigger the brain. But a bigger brain does not automatically equate to a higher intelligence or IQ.

The size of an animal's brain rougly corresponds with the amount of processing capacity required to accomplish its most basic survival activities (such as breathing, controlling body temperature, sensing moving, etc.). The larger the animal, the more processing capacity is required to accomplish those activities requiring a bigger brain. However, when the brain is larger in relation to the rest of the body, it can handle more mental tasks. Take, for example, the case of the sperm whale and the dolphin. The sperm whale stands out not only because of its massive physical size, it also has an its enormous brain. The dolphin, however, has been ranked in a variety of cognitive tests as the world's second-most intelligent mammal, surpassing the sperm whale.

Scientists use the encephalization quotient (EQ) as a general measure of brain size relative to body size. This calculation allows for a comparison of an animal's brain size to that of other animals. Humans have an EQ of around 7.5, which means that our brain is about 7.5 times larger than what we would expect for an animal of our body size. In comparison, bonobos and chimpanzees share a similar EQ of around 2.5, which means that their brain is about 2.5 the size we would expect for an animal of their body size. The higher EQ of bonobos and chimpanzees relative to other non-human primates is thought to reflect their advanced cognitive abilities and social complexity.

So, does the fact that males, on average, have a bigger cranial capacity than females imply that they are more intelligent? No. Although males usually have larger brains because of their greater body mass and height, the brain-to-body mass ratio remains similar between the sexes in each specie. The average EQs, broken down by sex, are the following:

Human female 6,37	Chimpanzee female 2,42	Bonobo female 2,31
Human male 6,29	Chimpanzee male 2,33	Bonobo male 2,36

Also, we should keep in mind that the encephalization quotient is not a proxy for intelligence: the gyrencephalic index is also key when it comes to neuronal density and overall cognitive function. So the size of the brain relative to body size is definitely not the only piece to this puzzle.

In humans, while studies have indicated that, on average, males and females generally exhibit distinct performance patterns vis-à-vis specific abilities, there are no overall sex differences in general intelligence (Halpern, D.F. & LaMay, M.L., 2000; Hunt, E., 2010; Mackintosh N., 2011; Sternberg R., 2020).

Are there functional advantages or adaptations associated with the increased or reduced size of occipital crest and nuchal lines?

The three species under observation display morphological differences in the braincase based on sex. Specifically, males in all three species exhibit a noticeable occipital crest and distinct nuchal lines in comparison to the opposite sex. It should be acknowledged, however, that in the case of bonobos and humans, this difference is less pronounced.

The occipital crest and nuchal line are bony prominences on the skull, particularly in some male primates. These features are often associated with the attachment of neck and jaw muscles, and their relative size is influenced by testosterone levels. Larger occipital crests and nuchal lines may provide greater surface area for the attachment of muscles, aiding in stabilizing the head during physical activities such as fighting, climbing, or other behaviors requiring strong neck and jaw muscles.

To put it another way, a greater muscle attachment area can offer biomechanical advantages for activities such as climbing, fighting, carrying heavy objects.

Male chimpanzees with enlarged occipital crests and nuchal lines may signal a heightened development of jaw and neck muscles. This can be advantageous for males involved in activities such as consuming tough foods (such as meat) or engaging in aggressive behaviors that demand robust biting or neck movements, such as hunting, competing for mates or for food resources with other predators. Additionally, it has been established that chimpanzees spend more time walking on four limbs and climbing trees than humans and even bonobos.

Are there evolutionary benefits linked to the evolution of a pronounced or less prominent brow ridge?

Among the three species, chimpanzees, especially males, exhibit the largest supraorbital torus. Positioned just above the eyes, its substantial size serves to avoid eye injury.

Scientists theorize that its purpose could be linked to protecting these areas from any impact that may occur, for example, chimpanzees when facing larger predators for food resources (gorillas).

A more prominent brow ridge could also provide some degree of protection for the eyes against environmental hazards such as sunlight, rain, and falling debris.

The supraorbital shape is far less pronounced in humans compared to that of Pan (or any other living ape).

What advantages may a shorter face and non-protruding jaw and teeth imply?

While chimps have a higher bite force than we do as humans, our facial skeleton is optimized for efficient chewing. The other primates' (chimpanzees and bonobos) more prognathic faces are less mechanically efficient (i.e., more muscle force has to be recruited to achieve a given bite force).

Having a flat face and well-aligned jaws allows for efficient movement of the jaw muscles and optimal positioning of teeth during chewing. This improves the breakdown of food, making it easier to digest and extract nutrients; reduces the strain on the jaw muscles and makes these activities more energy-efficient.

Moreover, an orthognathic face is beneficial for speech production. The precise movements required for articulating a greater range of sounds are facilitated by an alignment of oral structures.

What advantages may a larger face and protruding jaw and teeth imply?

While prognathic faces (chimp's and bonobo's) might be less mechanically efficient for chewing, their shape broadens the gap when opening the jaws, exposing the large canines as weapons.

Large canine teeth enable gripping, holding, and tearing. They are essential for killing, dismembering, and consuming prey. Their pointed shape and strong roots allow them to grip and tear flesh and bone, making them effective weapons and tools for sustenance.

If the jaw's (mandible) main purpose is to create bite forces (chew), what might explain their difference in shape?

A simple explanation for humans' reduced jaws is that they applied technology and culture in order to soften food before it entered the mouth. As cooking and other methods of food preparation grew more prevalent, our species could rely on a smaller jaw to get the job done (smaller jaw = less effort required).

In general, primates who consume foods that need vigorous or lengthy chewing have mandibular corpus proportions that are particularly deep and/or wide for their length; that is, larger mandibles are assumed to indicate higher feeding effort.

What might explain the difference between size and shape of the dentition across the species and between the sexes?

In the front and center of their mouths, primates have incisors, which are usually used to manipulate food, nibble, or do other things related to eating. And just behind the incisors are the canines, which can be used like the incisors or, in some species, are bigger to show off, deter, protect or attack.

Modern humans have smaller front teeth, and the canines look more like incisors. Since we do not use canines for sexual display or meat-tearing, they are less prominent (less energy required for the body to develop/maintain them).

Most primates exhibit sexual dimorphism in canine size, with female canines being smaller. But in some cases, the fact that both males and females of the same species have relatively similar sized canines suggests that their canine shape is more related to feeding than to aggression.

Further Discussion Questions

- Can environmental conditions, such as climate or habitat, be linked to the size variations among these three species?
- How do these adaptive changes align with shifts in primate behavior, ecology, or environmental conditions?
- What functional roles or purposes might the brow ridge serve in chimpanzees or the other species?
- What functions do the maxilla (face) and mandible serve?
- What impact would larger canines have?
- What is the purpose of the canines?
- What facts or habits talked about at the beginning of the lesson could explain why the mandible is more robust in some cases and less in others?
- What factors or behaviors may account for variations in dentition size?

Student Handout A

Trait	Description				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Overall size and appearance	dŋǊğ̆ɉǵǺ ʉɻ ʐ all, slenderʉ̭.	Slightly smaller, rounded, slim.	ModerateǺ size,Ǻ proporʉionate.	Slightly larger, more angular and wide.	æɾĞʑɻʉǺ ɰarge,Ǻ rugged, wideǺ or broadʉ̭.
Facial prognathism	Short and retracted face.	Slightly shorter	Moderate	Slightly extended and protruding	Long and projecting face.
Zygomatic arches	Does not extend past the external auditory canal.	Barely extends past the external auditory canal.	Moderate	Extends past the external auditory canal.	Extends far past the external auditory canal.
Supraorbital torus	Smooth	Slightly delimited	Delimited	Marked	Massive and prominent.
Nuchal Area	Smooth	Slightly arched, traces of nuchal lines.	Nuchal lines and occipital crest evident.	Nuchal lines and occipital crest marked.	Nuchal lines and occipital crest with bumpy surface.
Mandible	Small, narrow ascending ramus.	Reduced size, thinner structure.	Medium	Prominent jawline but less robust.	Large, robust, wide ascending ramus.

Student Handout B

Trait	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Overall size and appearance						
Facial prognathism						
Zygomatic arches						
Supraorbital torus						
Nuchal Area						
Mandible						
Mandibular canine (mm)						
Maxillary canine (mm)						
Cranial capacity (ml)						

Answer Key

Trait	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Overall size and appearance	3	3	3	5	2	3
Facial prognathism	3	4	4	5	1	2
Zygomatic arches	3	3	2	5	1	2
Supraorbital torus	3	4	3	5	1	2
Nuchal Area	2	3	3	5	1	2
Mandible	2	3	4	5	1	2
Mandibular canine (mm)	13,69 mm -+ 0,66 mm aprox.	13,72 mm -+ 0.27 mm aprox.	13,40 mm -+ 0,20 mm aprox.	22,88 mm -+ 0,61 mm aprox.	9,77mm -+ 0,17 mm aprox.	10,38 mm -+ 0,31 mm aprox.
Maxillary canine (mm)	14,92 mm -+ 0,18 mm aprox.	11,55 mm -+ 0,75 mm aprox.	14.75 mm -+ 0,27 mm aprox	23.51 mm -+ 0,77 mm aprox.	11,94 mm -+ 0,43 mm aprox.	14,16 mm -+ 0,11 mm aprox.
Cranial capacity (cm3)	350 cm3	375 cm3	370 cm3	400 cm3	1300 cm3	1400 cm3

LESSON 2

Behavior Assessment

Student Learning Objectives

- Define gender roles.
- Explore the similarities and differences in behaviors between chimpanzees, bonobos, and humans.
- Examine the behavioral patterns associated with sexually dimorphic behaviors in chimpanzees, bonobos, and humans.
- Compare and contrast the behaviors of males and females in each species social structure, including dominance hierarchies, parental care, and cooperation.
- Discuss how factors such as sexual selection, ecological pressures, and social dynamics have shaped the development and maintenance of sexually dimorphic behaviors across species.

Materials

- Digital Learning Equipment (computer; internet connection; projector; speakers)
- PowerPoint presentation (video links);
- Student handouts (C); & Answer Keys.

Procedure and Time Estimates

Activities	Background information for the class	Data collection	Data analysis & interpretation	Time Estimates (aprox)
Lecture	X			(10-15 min)
First assessment		X		(5-7 min)
Second assessment		X		(5-7 min)
Third assessment		X		(5-7 min)
Class discussion			X	(7-10 min)
Hypothesis/Theories			X	(15-20 min)

Background Information

Chimpanzees and bonobos are our closest surviving relatives in the animal kingdom. This means we share a common fore-father and mother millions of years before the three lines diverged and evolved into what we know now as chimps, bonobos, and humans (Figure 16).

To recap some of the earlier findings, the three species exhibit noticeable differences: compared with humans, chimpanzees and bonobos show a reduced height and body mass, as well as a smaller cranial capacity, a more protruding face and supraorbital torus, and a bigger mandible. Additionally, we now understand that the three species demonstrate distinct levels of sexual dimorphism.

Yet physical characteristics are not the only thing worth investigating, behavioral traits, as well, are worth scrutinizing.

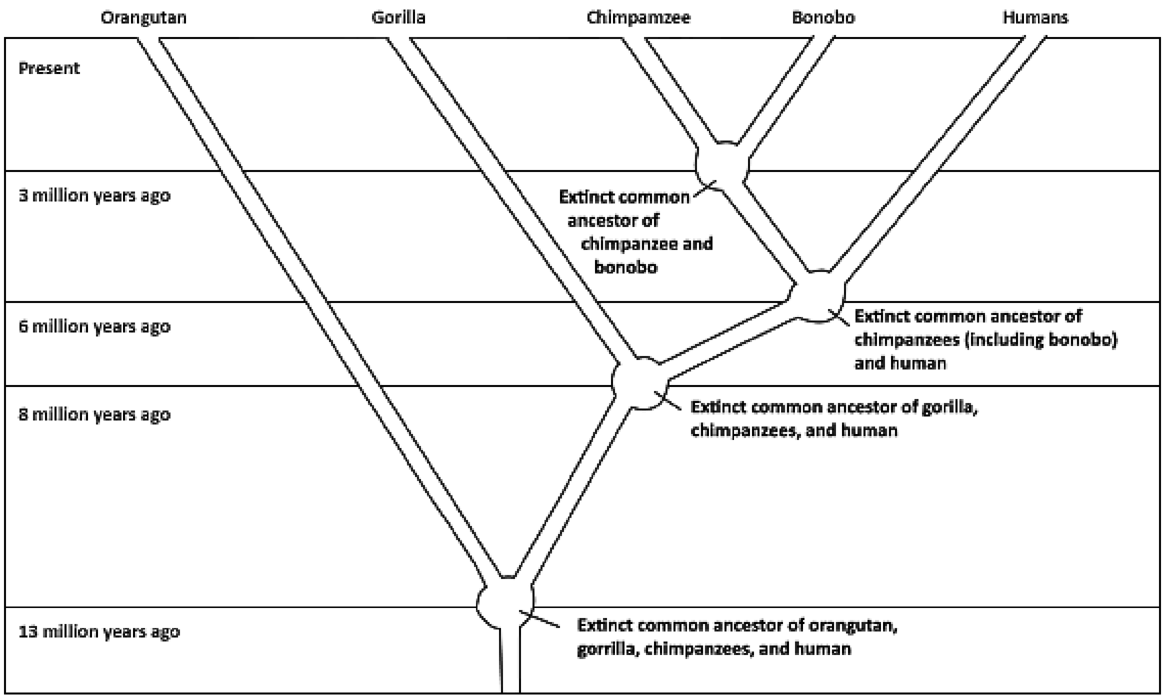
Definition of 'behavior'

Behavior refers to the actions or reactions of an individual or a group of individuals in response to different situations. A behavior can be intentional or unintentional, conscious or unconscious, and it serves a purpose, such as expressing emotions, communicating with others, fulfilling basic needs, or achieving goals.

Sexually dimorphic behaviors

Many behaviors exhibited by females differ from those of males, and sometimes these differences can be quite pronounced. In rare cases, one sex

Figure 16 - Evolutionary tree of primates



might show a behavior that the other never does. More commonly, the way a behavior is expressed or how often it happens varies between the sexes.

These behavioral differences are often referred to as "sexually dimorphic," drawing a parallel to the secondary sex characteristics (see Lesson 1 - Sexual dimorphism).

For instance, three key areas where sexually dimorphic behaviors are most evident are parental care, mating, and courtship.

In some bird species, males are known for their elaborate courtship displays, while females are responsible for building nests and incubating eggs. In many primate species, males are dominant and compete for access to females, while females are the primary caregivers for offspring.

Chimpanzees & bonobos: social behavior

Chimpanzees and bonobos live in communities with other individuals of their species. They form social groups where they interact and engage in various activities together. These communities can vary in size, with chimpanzee communities typically ranging from 10 to 100 individuals, while bonobo communities are generally smaller.

Chimpanzee and bonobos, within their communities, communicate with each other using a variety of sounds, gestures, and facial expressions. They use these forms of communication to express their needs and intentions.

Chimpanzees and bonobos spend their days engaging in various activities. They search for food, which involves foraging for fruits, leaves, insects, and sometimes hunting for small animals.

They also engage in social behaviors such as grooming each other, which helps maintain social bonds and cleanliness. Playful interactions, such as chasing, wrestling, and swinging from trees, are also common among them.

Bonobo and chimpanzee communities are quite dynamic, and members may move between groups.

Definition of ‘ethogram’

An ethogram is an inventory or list of the behaviors exhibited by an animal. It helps scientists study animals by keeping track of all the things they do, like how they move or make sounds. Ethograms can help us understand how animals behave and why they behave that way.

Figure 17 - Example of an ethogram from published research on two species of flamingo.

Behavioural state	Description
Walk / run	Bipedal movement along the ground at a slow/hurried pace. Running birds may have outstretched wings.
Rest /sleep	Motionless with head “tucked under wing” satnding or sitting, with eye(s) open or closed.
Preen / bathe	Cleaning and oiling feathers with bill. Or using water to wash feathers by scooping water over body with wings and/or bill.
Feed / forage	Consumption of food from feed trough or natural filtering (pumping water throught bill) in pools.
Stand	Motionless. Not alert (head is held low in front of body), not asleep or resting. General inactivity.
Alert	Neck held in erect S-shape with head on 90° angle, scanning surroundings.
Social	Long-duration positive social association defined as the following of one bird by another around the enclosure.
Courtship / nesting	Courtship: Long duration head-flagging (movement from side-to-side) or martching displays, or extended wing saluting (spreading of wings out to the bird´s sides). Nesting: Nest mound constructed using bill to gather damp substrate together,

Note. Figure 17. Example of an ethogram from published research on two species of flamingo. In What influences feather care and unipedal resting in flamingos? Adding evidence to clarify behavioural anecdotes, by P. Rose, & R. Kinnaird, & K. Wood, 2024. Animal Behaviour Science 277 106364. https://doi.org/10.1016/j.applanim.2024.106364.

Data Collection

NOTE: The instructions follow a sequence, introducing behaviors and audiovisual material. We recommend starting by introducing the five behaviors before observing the videos.

During this lesson, students learn about the behaviors of chimpanzees and bonobos, contrasting them with that of humans. Additionally, they will be encouraged to investigate potential distinctions in gender roles.

While students view videos to observe chimpanzee and bonobo behavior, for human behavior they draw on their own experience. To this end, students participate in group discussions where they can share their thoughts and perspectives. The discussions are guided by open-ended questions that encourage critical thinking and reflection.

Throughout the process, students will be given feedback and support from their peers and the instructor to help them refine their ideas.

Audio-visual assessments

1. Aggressive behavior

Definition: Behaviors that are meant to harm or intimidate another organism. It can include actions such as attacking, biting, growling, hissing, or displaying threatening body language. Aggression can be used to establish dominance, protect resources, or in some cases, as a means of hunting.

Instrument:

Video 1 - Agressive Behavior, Chimpanzees

BBC Earth (2015, Oct 21) Chimpanzees Attack Young Male | Life Story | BBC [Video] YouTube.

Video 2 - Agressive Behavior, Chimpanzees

AncientAncestors (2023, Mar 18) Female Chimpanzee Attacked By Dominant Male Nature Bites (EDIT) [Video] YouTube.

Video 3 - Agressive Behavior, Bonobos

Animal Cognition (2016, Jul 31) Bonobos make love AND war [Video] YouTube.

Video 4 - Agressive Behavior, Bonobos

横山拓真の霊長類研究所 (2019, Oct 19) Aggressive Behaviors among Wild Bonobos! [Video] YouTube. URL

Method: Upon careful observation, students write a brief description of the behaviors that were observed or discussed in the videos. If the videos lack commentary, you can refer to the lines provided in the description box to assist students in their observations (Caution: videos may contain explicit content).

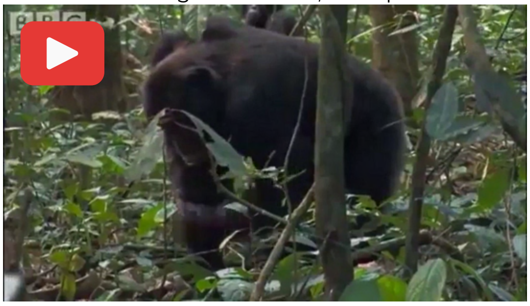
Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Aggresive behavior						

2. Meeting an outsider

Definition: The term refers to the initial interaction or meeting between two animals that have not previously encountered each other. This typically occurs when the animals come from different social groups, territories, or environments. During this first encounter, the animals may engage in various behaviors ranging from peaceful and curious exchanges to aggressive or defensive responses.

Instrument:

Video 5 - Meeting an outsider, Chimpanzees



Ancient Ancestors (2023, Mar 18) Violent chimpanzee attack - Planet Earth - BBC wildlife (EDIT) [Video] Youtube.

Video 6 - Meeting an outsider, Bonobos

National Geographic España (2014, May 26) Bonobos [Video] Youtube.

Method: Upon careful observation, students write a brief description of the behaviors that were observed or discussed in the videos. If the videos lack commentary, you can refer to the lines provided in the description box to assist students in their observations (Caution: videos may contain explicit content).

Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Meeting an outsider						

3. Sharing food

Definition: Refers to the behavior of two or more animals dividing or giving away a portion of their food resources to other members of their group. We define food sharing to be the situation where the resource owner shows tolerance and allows a competitor animal to consume a part of its food although it has the ability to fight and try to keep all of its food.

Instrument:

Video 7 - Sharing food, Chimpanzees

The Bulindi Chimpanzee & Community Project (2021, Mar 3) Wild chimpanzees sharing food: #WorldWildlifeDay2021 [Video] Youtube.

Video 8 - Sharing food, Bonobos

横山拓真の霊長類研究所 (2023, Jan 31) Peaceful food sharing among wild bonobos! Observations of Bonobos #100 [Video] Youtube.

Video 9 - Sharing food, Bonobos

Gunter32804 (2019, Sep 20) Feeding Time at Lola Ya Bonobo [Video] Youtube.

Method: Upon careful observation, students write a brief description of the behaviors that were observed or discussed in the videos. If the videos lack commentary, you can refer to the lines provided in the description box to assist students in their observations (Caution: videos may contain explicit content).

Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Sharing food						

4. Interaction with mother

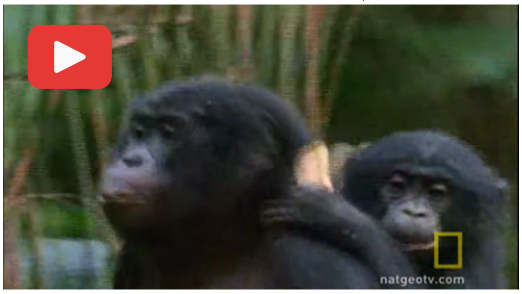
Definition: Ways in which newborns or young animals interact with their mother, including the relationship between mother-offspring after the first few years of care.

Instrument:

Video 10 - Interaction with mother, Chimpanzee

BBC Earth (2012, dic 4) Cutest Baby Chimp Learns from Her Mom | Early Learnings | Attenborough: Trials of Life [Video] Youtube.

Video 11 - Interaction with mother, Bonobo



National Geographic (2009, Feb 3) Bonobo: the Female Alpha [Video] Youtube.

Method: Upon careful observation, students write a brief description of the behaviors that were observed or discussed in the videos. If the videos lack commentary, you can refer to the lines provided in the description box to assist students in their observations (Caution: videos may contain explicit content).

Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Interaction with mother						

5. Sexual behavior

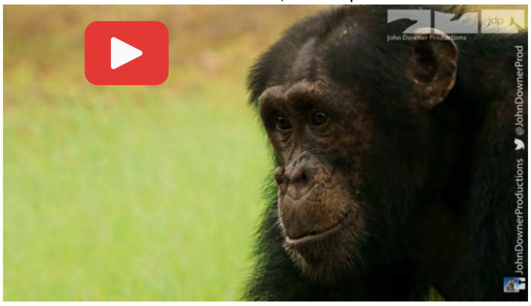
Definition: Sexual behavior in animals refers to the actions, activities, and interactions that involve the expression of sexuality, the pursuit of sexual pleasure or for the purpose of reproduction.

Instrument:

Video 12 - Sexual behavior, Chimpanzee

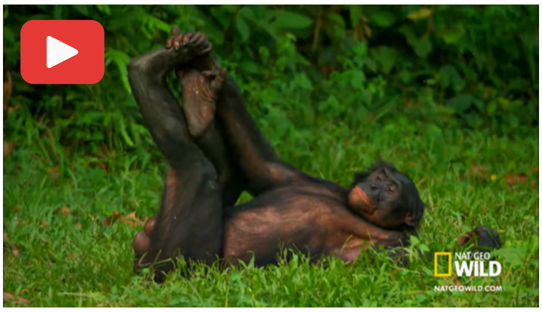
BBC Earth (2022, Feb 14) Chaos Erupts in Chimpanzee Tribe | Dynasties [Video] Youtube.

Video 13 - Sexual behavior, Chimpanzee



John Downer Productions (2018, Oct 25) Cheating Chimp Gets Caught In The Act! [Video] Youtube.

Video 14 - Sexual behavior Chimpanzee, Bonobo



HotelsFace (2021, Jun 9) Bonobo Love - Wild Wives of Africa [Video] Youtube.

Method: Upon careful observation, students write a brief description of the behaviors that were observed or discussed in the videos. If the videos lack commentary, you can refer to the lines provided in the description box to assist students in their observations (Caution: videos may contain explicit content).

Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
Sexual behavior						

Data Analysis

In this lab phase, students are tasked with reviewing the data gathered in the preceding section. This entails tasks such as rectifying errors or inconsistencies in the collected information to ensure result accuracy, changing and organizing data so it is easier to comprehend and process, as well as find patterns or trends in the data.

Note: Students discuss or work collectively.

Comparative analysis between the species

Aggressive behavior

Aggressive behavior is a common aspect of chimpanzee everyday life and is typically displayed in a variety of contexts. Chimpanzees are social animals that live in communities with complex social hierarchies, and aggression is often used to establish dominance and maintain social order.

One of the most common forms of aggression in chimpanzees is physical aggression, which can include hitting, kicking, stamping on, dragging, slamming, biting, scratching, and grappling. The victim may scream loudly, squeak or whimper, and during an actual attack, a victim may crouch passively, struggle to escape or turn and retaliate. Physical aggression is often used in disputes over food, mates, and territory, as well as during confrontations between dominant and subordinate individuals.

In other cases, the aggressive interaction between two chimpanzees leads to the involvement of others. Sometimes, an individual who ranks higher than both participants may charge toward or gently hit one or both of them, thereby ending the incident. But chimpanzees are also observed to gang up to attack a victim.

Chimpanzees also display a range of non-physical aggressive behaviors, such as a charging display, screaming, and throwing objects. These behaviors can also be used to establish dominance or to communicate frustration or anger.

Humans and chimpanzees have some notable differences in aggressive behavior as well. One big difference is that humans can control their aggression through cultural and social norms like laws, moral codes, and other social conventions.

Also, another clear difference is that chimpanzees tend to be more reactive and impulsive, while humans can show more planned and deliberate forms of aggression. Humans may plan acts of violence or aggression as part of organized crime or war, but chimpanzees are more likely to engage in spontaneous acts of violence in response to immediate threats or attempts to take over their territory.

Bonobos have long been considered more peaceful than chimpanzees and are often nicknamed the "make love, not war" apes. However, recent research suggests that bonobo society may be more complex than previously thought, showing that they, too, can engage in aggressive behaviours. Agression in bonobos has various forms, including physical violence, threats, and displays of dominance. As with chimps, it is often related to competition for food, mates, and other resources.

Interestingly, writing in the journal *Current Biology*, Mouginot Maud and colleagues (2024) revealed that male bonobos commit acts of aggression (pushing, biting, chasing) nearly three times as often as male chimpanzees. The frequent bonobo aggression often involved a single male attacking another male, since — unlike chimpanzee males — bonobo males would get into serious trouble if they showed hostility toward females. Dr. Mouginot suggested that male bonobos might find it easier to act aggressively because, in their female-dominated society, they do not encounter the dangers associated with male alliances.

Attacking other males is also a factor of reproductive success. “Male bonobos with high-ranking mothers often challenge other males with their mother’s support, which can boost their reproductive success,” observes Takeshi Furuichi (National Geographic). As such, females play an active role in male success. Mouginot suspects that female bonobos are not attracted to aggression itself, but rather to high-ranking males who do not shy away from using force to ward off rivals when females are ready to mate. In one study, the more aggressive male bonobos had significantly more offspring than the less aggressive ones. Also, by banding together, female bonobos dominate males and can choose their own mate. Thus, female-on-male aggression also occurs.

Critics of Dr. Mouginot's research seek to qualify the nature of bonobo aggression: there is no sexual violence among bonobos as seen in chimpanzees, and the intensity of aggression among bonobo males is lower. In fact, lethal violence is absent. While male bonobos pushed, chased, and bit other males more often than chimps, there is no evidence of rape or infanticide, which are often observed among chimpanzees. They also suggest that the matriarchal society and female power structure of bonobos are the reasons male aggression does not turn fatal. Moreover, unlike chimpanzees, bonobos tend to resolve conflicts through social bonding and sexual behavior rather than physical aggression. For example, if two bonobos have a conflict, they may engage in sexual behavior or mutual grooming to de-escalate the situation and restore social harmony.

Meeting an outsider

Chimpanzees often patrol the edges of their territory. During patrols, chimpanzees often smell or see members of the neighboring group, and their reactions range from being quiet and avoiding or running away to being aggressive and chasing or fighting. Chimpanzee males and, to a lesser extent, females who are adults can be extremely violent to members of other groups.

Intergroup interactions between bonobos are less violent than those between chimps, even though bonobos are territorial and males and females may be aggressive toward members of other groups during hostile intergroup interactions. Most of the time, these fights do not end in violence. Instead, one side just leaves the disputed territory without any trouble. Also, interactions between groups can be very social, with people from both groups sitting close together, playing, and even mating in some situations. It has not been reported that bonobos perform border patrols like chimps, and there has not been any proof that they are dangerously aggressive.

Among humans, when two people first meet, they are often guarded and cautious, as they have no previous experience to rely on in assessing the other person's intentions or character. As they begin to interact more, they may gradually lower their guard and become more comfortable with each other, building a sense of trust and rapport over time.

However, this cautious approach is not universal. In certain circumstances, initial encounters can be marked by hostility or aggression. This is especially true in situations where fear, prejudice, or high levels of stress are present. When people are influenced by negative emotions or biases, they may interpret the presence of a stranger as a threat, leading to confrontational or even violent behavior.

Sharing food

When feeding with other chimpanzees, males are far more inclined to share food than females, who are more prone to engage in competitive behavior over the actual food items or the feeding locations (among adult female chimpanzees, food competition is the main cause for conflict).

If one female in the group happens to have an excess of food, unrelated females are not likely to approach her to beg, and if they do, they will likely receive nothing. In most cases, they will wait until the dominant chimpanzee has finished eating and moved on before taking over the feeding site.

On the other hand, female bonobos have no trouble sharing food with other females, but they are notorious for eating/co-feeding to the exclusion of males in the group. Where food is abundant, female and male bonobos do not vary in their food intake at all, and parties may be led to feed by either males or females. If food is scarce, however, females tend to visit the food patch sooner and consume more food during the first stages of a bout.

Humans often share their meals with one another, and this behavior has cultural, social, and psychological implications. Sharing food with others is a traditional method of showing hospitality and charity to others. Sharing meals with people fosters sentiments of warmth, belonging, and connection, all of which have positive psychological effects. Eating meals together with family members, friends, or co-workers promotes a feeling of community, forges bonds, and improves communication.

Interaction with mother

In the three species, the relationship between a mother and her offspring is marked by a high level of association, protection, support, and help, as well as many behaviors that show affiliation.

In chimpanzees, the bond between a mother and child usually grows into a friendship as the offspring gets older, especially between a mother and her adult daughter, which is the strongest bond between chimpanzee adults.

A female bonobo continues to care for her son even after he has reached sexual maturity, sharing food and engaging in grooming and other forms of physical affection. Females often form strong bonds with their male offspring, which can last throughout their lives. On the other hand, it is speculated that when female offspring enter maturity, they leave their mother to join other troops.

The relationship of a human mother and her child changes after the child reaches adulthood. While the nature of the relationship shifts from one of primary caregivers to a more equal relationship between two adults, the bond between mother and child often remains strong. In many cases, a mother and adult child continue to maintain a close relationship, regularly communicating and spending time together. And in some cases, the mother continues to provide emotional support and guidance to her child as they navigate the challenges of adulthood.

Human mothers usually become very attached to their children, but fathers can also form strong emotional bonds. However, chimpanzees and bonobos males are hardly involved in caring for the young.

One aspect of bonobo social behavior that has been studied is the role of mothers in facilitating mating opportunities for their sons. Mothers use their social influence to help their sons gain access to females and increase their mating opportunities.

In bonobo societies, at times males compete aggressively (intra-male) in an attempt to gain access to females, which could lead to violent encounters. However, mothers tend to intervene in these conflicts and use their social influence to help their sons gain access to females without them having to engage in violent competition.

Sexual behavior

Chimpanzees have three different ways of mating. The first way is without competition, the second involves a dominant male preventing others from mating, and the third is when a male and a female leave the group for a while to mate (courtship). Aggression and dominance often play a significant role in sexual interactions.

Both male and female bonobos engage in various sexual activities. They have a very relaxed attitude towards sex, and it is a common behavior among them. Both male and female bonobos can engage in sexual activities with multiple partners. They may engage in genital rubbing, oral sex, and even same-sex intercourse. They also use other non-sexual behaviors, such as kissing and grooming, as a part of their sexual repertoire.

Bonobo's sexual behavior is often observed during tense events, such as after fights or when two groups meet. They also commonly engage in sexual activity while feeding. Compared to most other primates, bonobos have a notably high frequency of sexual contact. However, their rate of reproduction remains low. In the wild, it mirrors that of chimpanzees, with females typically giving birth to a single offspring every five years. This combination of a high sexual drive and slow reproduction is reminiscent of nonreproductive sex, a trait they share with humans.

Sexual behaviors in humans encompass more than just physical acts, emotions also play a significant role.

Male chimpanzees are drawn to females in estrus, however, like bonobos and humans, chimpanzees do not have a strict mating season. They can engage in sexual activities throughout the year.

Data Interpretation

Regarding behavior, which species exhibit more similarities and differences among the three?

Studying bonobos and chimpanzees provides valuable insights into the origins of human behavior and social structures due to their many commonalities. In the late 1970s, chimpanzees became the preferred model for such studies due to their cooperative hunting, food sharing, tool use, power dynamics, and warfare, among other traits. This decision perpetuated the idea of male superiority, as in chimpanzee society, males dominate females and exert their power through brutal means. The "female-dominated" society of bonobos was left behind in terms of scientific inquiry.

In more recent times, bonobos are considered to exhibit more similar behaviors to humans than chimpanzees in several aspects (De Waal, 1995). However, their sexuality is the most notable and frequently compared behavior, despite scientists determining that humans do not engage in the practice to the same extent as bonobos (De Waal, 1995).

Do the three species exhibit a social hierarchy?

Each chimpanzee community has a dominant male chimp known as the alpha male and is at the top of the social hierarchy. He is the leader and is responsible for protecting the group. Other males in the community have their own ranks, and females also have a social order.

The higher-ranking individuals have more privileges, such as access to food and mating opportunities.

A typical bonobo community is led by a dominant female, known as the alpha female. She is usually the oldest and most respected female in the group. The other females in the community, including her daughters and grand-daughters, form her social circle. The alpha female has a lot of influence and makes important decisions for the group.

Within the community, there are also male bonobos who have their own hierarchy. The males' status is determined by their relationships with the females. Generally, the males who have good relationships with the females are more likely to have higher status and be more influential (mother influence on mate choice).

Humans have social hierarchies and can vary depending on different factors like culture, geography, and historical context. They usually are based on positions, roles, financial success, and levels of power or influence. For example: One could argue that the top of the social hierarchy are people who have significant authority, like political leaders, business executives, or influential figures in society. They usually make important decisions that affect many people and have the most control over resources and opportunities.

What benefits are there to being the first to access food resources?

For each species, access to sufficient and nutritious food is crucial for individual survival and overall fitness. In environments where resources are limited, competition for food ensures that individuals can meet their nutritional needs, which in turn contributes to their chances of survival and reproductive success.

Also, bonobos and chimpanzees live in communities that consist of multiple individuals, with hierarchies and social relationships. Within these communities, individuals may compete for food to establish or maintain their social status or to gain access to mates and reproductive opportunities. Humans, too, have developed social structures that often involve competition for resources, including food, as individuals seek to provide for themselves and their families.

Among adult female chimpanzees, conflicts primarily arise due to competition for food because in general, females who eat more are more likely to be healthier, have more kids, and raise children who are likewise healthier because they eat more.

Where food is abundant, female and male bonobos do not vary in their food intake at all, and parties may be led to feed by either males or females. If food is scarce, however, females tend to visit the food patch sooner and consume more food during the first stages of a bout. The bonobo female feeding priority may result from male deference (males could influence female mate choice by allowing them to feed first) and the practice of female coalitions (food defense).

Is reproduction the only reason why the three species engage in sexual activity?

With chimpanzees, sexual behavior is mainly, but not exclusively, geared for reproduction. Male chimpanzees are drawn to females in estrus. But since male and female chimpanzees engage in sexual activity more often than necessary for reproduction, it suggests that mating may serve other purposes such as buttressing social bond between males and females, and strengthening group cohesion.

Bonobos, in comparison, have a more active sex life that is often not related to reproduction. It is believed that their sexual behavior, apart from bringing pleasure, helps to reduce tension, encourage bonding, and promote peaceful relationships between members of their group who are not related. Also helps to regulate competition and facilitate sharing of food and they use sexual behaviors to repair relationships between individuals who were fighting or to reduce distress.

One of the main similarities between humans' and bonobos' sexual behavior is that the two species can have sex at any time, and females use it as a way to obtain male favors. Experts believe that the reason why sex and reproduction are partly separate in humans is that sex helps to create mutually beneficial relationships between men and women. Women can mate all year round, and use sex to get men to commit to taking care of their children, which helps form the nuclear family. This arrangement allows women bo raise more children than they could on their own (De Waal, 1995 & De Waal, 2013).

While humans typically form nuclear families consisting of a mother, father, and their children, bonobos and chimpanzees do not have the same family structure. Instead, they engage in sexual behavior with multiple partners. This means that in these primate species, individuals may mate with different individuals at different times, rather than forming exclusive long-term pair bonds. Additionally, while some individuals may care for and protect their offspring, there is not typically a fixed family unit involved in their upbringing.

How do these three species arrange themselves socially?

Chimpanzee groups are characterized by male dominance, where fully grown males are prominently dominant over females. They maintain their supremacy through aggression and violence, and it is rare for a female to dominate a fully grown male. Males form strong bonds with each other to hunt and protect their shared territory, while females live in overlapping home ranges within the territory but do not have strong bonds with other females or males.

In contrast, bonobo communities are generally peaceful and egalitarian. The strongest social bonds are formed among females, although they also bond with males. A male's social status depends on his mother's position, to whom he remains closely bonded for her entire life. Some scientists even argue that bonobo society is not only female-centered but also appears to be female-dominated.

Human society is the most diverse among primates, with both males and females forming social bonds. While males tend to unite, females also bond with those of their own sex.

Which species exhibit a greater inclination towards aggression?

Aggression is a behavior that is observed in many animals, including humans, chimpanzees, and bonobos. However, while the three species can all be aggressive, the frequency and severity of aggression differ between the three species.

Mouginot's research highlights that male bonobos are more aggressive toward other males than females, but their aggression is less severe compared to chimpanzees and humans. Bonobos resolve conflicts more peacefully, using social bonding and sexual behavior rather than violence. Richard Wrangham suggests that bonobo aggression is less dangerous, so it is not suppressed as much. Mouginot agrees, noting that bonobos don't kill each other, unlike chimpanzees.

Overall, while aggression is still present in bonobos, it is less severe than in chimpanzees and humans, and their unique social structure and problem-solving abilities allow them to use alternative methods to resolve conflicts.

What factors contribute to the difference in levels of aggression between bonobos and chimpanzees? Or even humans?

One reason for this is thought to be because bonobos have evolved to select against aggression. This means that over time, individuals who are less aggressive and more cooperative could be more successful in reproducing and passing on their genes.

Some scientists believe that bonobos evolved to select against male-to-female aggression because cooperation and social bonding enhanced their survival and reproductive success more effectively than aggression. Male-to-female aggression is not tolerated in bonobo society. While males can be aggressive toward other males, females often band together to oppose a male if his behavior deserves it. This social cooperation helps bonobos efficiently find food, protect themselves from predators, and attract mates. Moreover, females play a central role in bonobo society, and males who form strong, non-aggressive social bonds with females are more likely to gain access to mates and resources.

The reduced prevalence of intense aggression among bonobos cultivates robust social bonds and cooperation within their groups, promoting group cohesion and reducing the probability of severe conflicts. Additionally, it fosters a more inclusive environment, particularly advantageous for females, and facilitates a more equitable distribution of resources among group members.

In summary, the cooperative and less male to female aggressive tendencies of bonobos are linked to increased reproductive success, as positive social interactions and strong bonds enhance the overall fitness of individuals within the group. In contrast, the competitive and aggressive dynamics prevalent in chimpanzee societies may heighten stress levels and potentially limit reproductive success for specific individuals.

Further Discussion Questions

- Are there parallels between the behaviors and traditions observed in bonobos, chimpanzees, and human societies?
- Is there an uneven distribution of resources, privileges, and opportunities?
- How does obtaining first access to food resources contribute to individual survival and reproductive success in bonobos, chimps, and humans?
- What are some other benefits of mating?
- Do they display a greater degree of male or female dominance? Is it equal?
- Do all the species show aggressive behavior? If so, which one shows them less frequently?
- What are the primary social structures and behaviors of bonobos that contribute to their lower levels of aggression compared to chimpanzees?
- What impact does conflict resolution strategies, such as cooperation and social bonding, have on reducing aggression within primate societies?
- How do environmental factors, such as habitat and availability of resources, influence the aggression levels in bonobos, chimpanzees, and humans?

Student Handout C

Behavior	Bonobo		Chimpanzee		Human	
	Female	Male	Female	Male	Female	Male
meeting an outsider						
sharing food						
interaction with mother						
within-group aggression						
sexual behavior						

Answer Key

Behavior	Bonobo		Chimpanzee		Human	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**
meeting an outsider	territorial, but rarely aggressive		territorial and aggressive towards outsiders	territorial and aggressive towards outsiders	do not react aggressively but can show caution	
sharing food	do not react aggressively but can show caution	males share food with females	reason for the majority of females fights	hunters share food (esp. with females)	do not mind sharing	
interaction with mother	caregiver	no relation	caregiver	no relation	caregiver - nuclear family (mother, father and children)	
within-group aggression	Male-to-male non-fatal aggression. Females band together to go against a male if necessary		aggressive behavior is common impulsive		show aggressive behavior, but also restraint planned and deliberate	
sexual behavior	for pleasure and as a way to avoid conflict females have “extended receptivity”		reproduction and “political” gain - only during estrus	reproduction	multiple reasons for sex females have “extended receptivity” not as often and freely as bonobos	

LESSON 3
Conclusion

Student Learning Objectives

- Gain insight into sexual dimorphism and its importance within the field of evolutionary biology.
- Explore the connection between an organism's physical characteristics and its behavioral patterns.
- Discuss the role of sexual selection, competition for mates, and reproductive strategies in shaping differences in size, morphology, and behavior between males and females.
- Explore the interplay between genetic factors and environmental influences in driving sexual dimorphism.
- Analyze the influence of culture and social learning on gender roles in chimpanzees, bonobos, and humans.

Materials

- Digital Learning Equipment (computer; internet connection; projector; speakers);
- PowerPoint presentation;
- Completed Student handouts (A, B, C); & Answer Keys.

Procedure and Time Estimates

Activities	Background information for the class	Data collection	Data Analysis & Interpretation	Time Estimates (aprox)
Summary	X	X		(5-7 min)
Hypothesis/Theories			X	(15-20 min)
Class discussion			X	(15-20 min)
Retrospective/prospective predictions			X	(10-15 min)

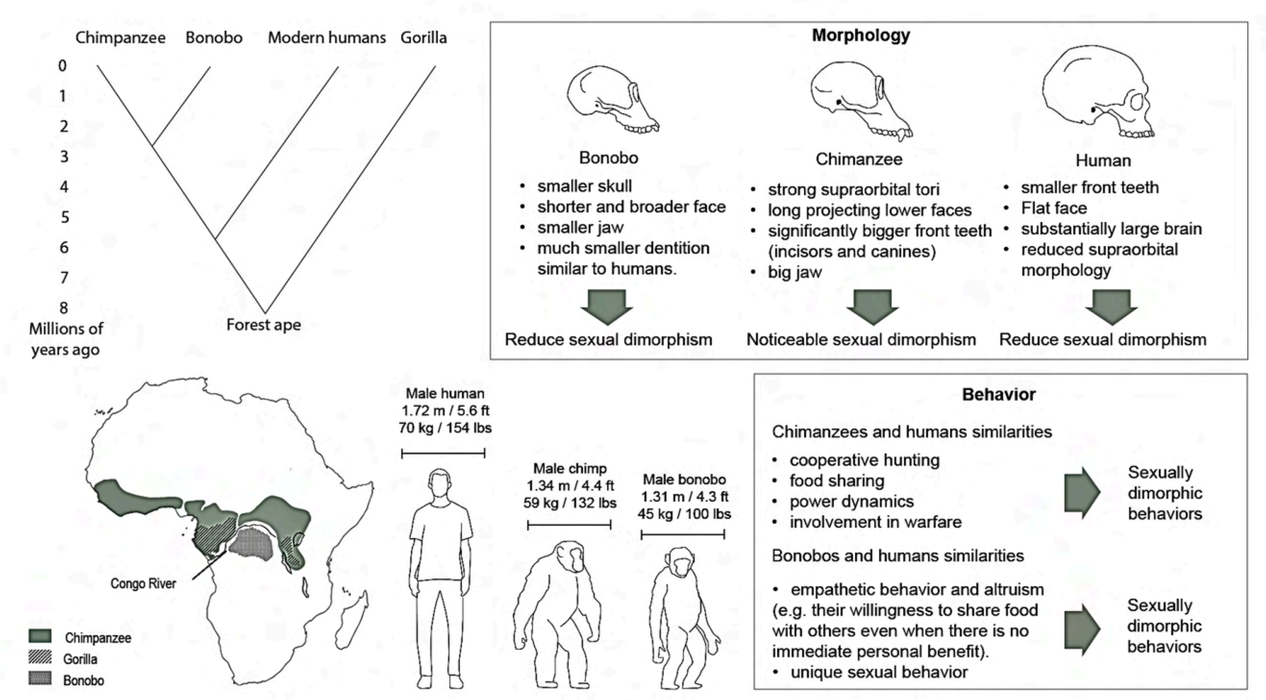
As the lab nears its end, the final conclusions still need to be formulated. In the preceding two lessons, we engaged in various activities: observing, posing problems along with potential solutions, conducting experiments, collecting data, and ultimately analyzing them to ascertain the validity of our hypotheses. Assuming the instructional methodology is sound, we should possess two substantial collections of data, information, hypotheses, and theories that require integration.

Background Information

Chimpanzees and bonobos hold the closest familial ties to us among all living creatures. This implies that we share an ancient ancestor, millions of years ago, from whom these three lineages branched off and gradually evolved into the distinct beings we recognize today as chimpanzees, bonobos, and humans.

When comparing humans to chimpanzees and bonobos, it is evident that both primate species have smaller stature and body mass in comparison. They also possess smaller cranial capacity, more pronounced facial features and supraorbital torus, and larger mandibles.

Figure 18 - Summary of Lessons 1 & 2



In terms of sexual dimorphism, the contrast between male and female chimpanzees is more pronounced than in humans and bonobos. Male chimpanzees often have larger and more prominent canine teeth than females. Additionally, male chimpanzees have larger and more robust skulls. In humans and bonobos, cranial sexual dimorphism exists but is less pronounced, typically reflected in males having slightly larger skulls and more prominent brow ridges. However, in humans, sexual dimorphism is also evident in overall size. whereas in bonobos, the differences are more subtle, with less variation in size.

Regarding behavior, humans are frequently compared to chimpanzees due to their cooperative hunting, food sharing, power dynamics, and involvement in warfare, among other traits. On the other hand, bonobos display similarities to humans through their empathetic behavior and altruism (e.g. their willingness to share food with others even when there is no immediate personal benefit). Furthermore, bonobos display unique sexual behavior that overlaps with the "extended receptivity" of female sapiens, although humans do not partake in this practice to the same degree as the bonobos.

Data Interpretation

How does the anatomical sexual dimorphism of the skull relate to behavior?

Physical and behavioral traits are correlated: For example, in chimpanzees, the prominent brow ridge, jaw, and canine teeth are linked to their social structure where males compete for females and maintain harems. On the other hand, humans and bonobos have fewer physical differences between males and females, and their less pronounced features connect to their cooperative and less letal aggressive behaviors.

Scientists explain this connection through the self-domestication hypothesis (Hare, B. 2017 p. 162). This idea suggests that some species have evolved to become gentler, less aggressive, and more tolerant of each other over time. This process, known as self-domestication, has been observed in various animals, such as marmoset monkeys and common rats.

Just as with other animals, humans are thought to have undergone a similar process. This change, known as human self-domestication, involves becoming less aggressive and more friendly. This shift towards working together helps groups stick together and share resources better, compared to the earlier more competitive and aggressive tendencies.

The development of social rules and cultural practices that encouraged cooperation and discouraged violence played an important role in this process. Tolerance also increased, allowing for the formation of larger and more complex social groups, leading to benefits like division of labor.

In the 1950s, Dmitri Belyaev began raising wild silver foxes in captivity. He selected and bred the ones that were least aggressive toward humans. In just 20 generations, he turned them into foxes that behaved like our pet dogs, wagging their tails and having floppy ears, curly tails, and smaller skulls. Belyaev's experiments demonstrated that choosing animals for friendliness can lead to other domestication traits. Hare believes a similar process occurred in bonobos, even without direct human involvement.

Chimpanzee communities often involve rape, murder, and conflicts with neighboring groups. In contrast, bonobo societies are much more peaceful. Hare suggests that the ancestors of bonobos, who had behaviors similar to chimps, ended up in an environment where aggression was not advantageous. Through evolution, the most cooperative individuals were favored, leading to the development of a "self-domesticated" ape in bonobos.

In the world of chimpanzees, competition with gorillas for food was intense. This led to fierce competition among chimpanzees themselves for whatever resources remained. Females were often overpowered by males in both the pursuit of mates and resources.

Meanwhile, in the southern realm of bonobos, the situation was different. With an abundance of food, females could gather in larger groups, build strong social connections, and resist male advances more effectively. In this plentiful environment, males who chose cooperation over aggression, forming alliances with females instead of relying on brute force, were more likely to find mating opportunities.

But Hare's proposal does not convince everyone. Some researchers express skepticism, pointing out the uncertainty about whether bonobos evolved from a chimp-like ancestor or vice versa. If the latter is true, the focus should be on why chimps became highly aggressive rather than why bonobos evolved to be more amiable. Hare acknowledges this challenge, especially given the absence of fossils for either species.

These same researchers argue that the differences between bonobos and chimps are due to other causes, such as diet or habitat.

One critique of Hare’s self-domestication hypothesis comes from recent research showing that male bonobos often display more aggressive reactions toward other male primates. This could challenge Hare’s argument that the self-domestication of bonobos was driven by a reduction or absence of aggressive behavior. However, one should clarify that while bonobos engage in male-to-male aggression about three times more often than chimpanzees, this aggression is far less lethal and rarely escalates. Notably, there have been no reports of bonobos killing each other, in contrast to chimpanzees, which helps explain why bonobos are more willing to use aggression in everyday social interactions.

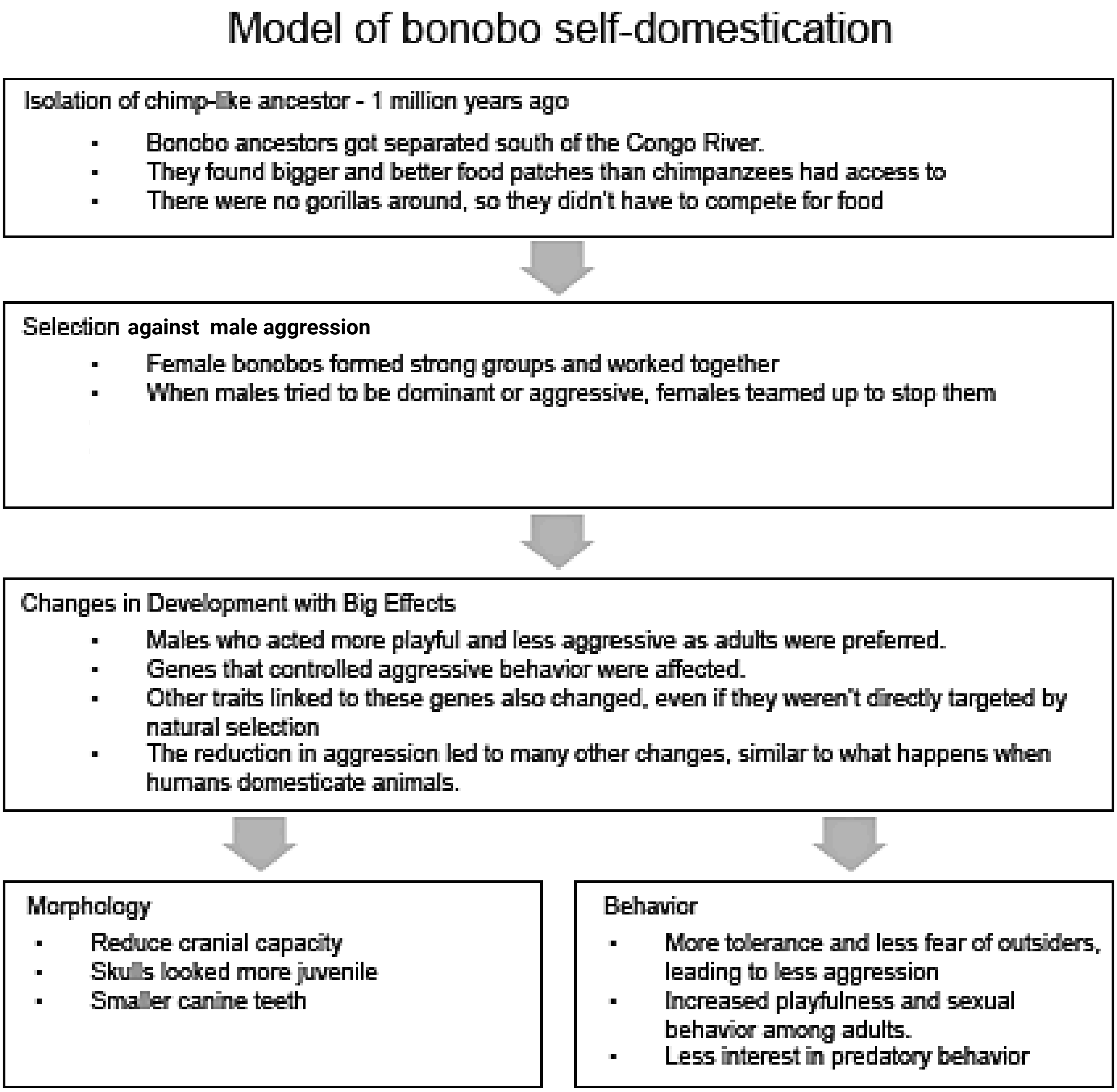
While discussing how "more aggressive" male bonobos tend to have greater access to females, Mouginot clarifies that female bonobos may not be attracted to aggression per se. Instead, they prefer high-ranking males who use controlled force to fend off rivals when females are ready to mate. Moreover, high-ranking mothers often support their sons increasing their chances of reproductive success. It is also crucial to note that male-to-female aggression is not tolerated in bonobo society.

While Mouginot's findings might initially seem to challenge Hare's self-domestication hypothesis, it is possible that the two perspectives could actually complement each other. Perhaps the key is not the absence of aggression in bonobos, but rather the way aggression is expressed and regulated. Mouginot's research shows that male bonobos may display aggression more frequently toward other males, but this behavior tends to be non-lethal and socially moderated—often kept in check by female alliances and maternal support. This could suggest that what evolved in bonobos was not the complete suppression of aggression, but a shift toward less harmful, more socially embedded forms of it. If that is the case, Hare's theory might still hold, though in a more refined or expanded form. Scientific understanding often develops in this way: theories are proposed based on current evidence, and as new data comes to light, they are revised or reinterpreted. Rather than disproving earlier ideas, newer findings can open the door to more complex and inclusive explanations.

Traits exhibited by bonobos that correspond with the theory of self-domestication include:

- Bonobos exhibit reduced levels of aggression male-to-female and within groups compared to other primates. They also display passive ways of dealing with social stress.
- Female bonobos are receptive for a longer time during their sexual cycle.
- Bonobos engage in less aggressive behavior towards members within their group and members of other groups compared to other primates.
- Bonobos tend to respond to social stress in a more passive manner and female bonobos have longer periods of sexual receptivity compared to other primates. Bonobos exhibit a decreased cranial capacity, facial projection, mandible, and tooth size, as well as a reduced difference in size between male and female canines (canine dimorphism).
- As adult bonobos, there is an increase in playful and socio-sexual behaviors, and willingness to share food voluntarily.
- Bonobos rely more on their mothers for care and support, and they tend to develop their social skills more slowly in areas related to finding food and competing for it.
- Bonobos display greater sensitivity to human social cues and are more proficient in tasks that require social tolerance.
- Bonobos exhibit increased sexual behavior, similar to many domesticated animals.

Figure 19 - Model of bonobo self-domestication



How are genetics and behavior related?

The case of the bonobos may illustrate how behavior, collectively practiced in the form of culture, impacts the genotype level through so-called Baldwin effects ("behavior as selection pressure"). Self-domestication in bonobos has, in turn, shaped the very morphology of the species and lessened its sexual dimorphism.

If a species undergoes self-domestication, changes in behavior, morphology, and cognitive abilities might also occur. Studies (Hare, 2011) show that when animals select to be less aggressive, it can result in modifications to their physical appearance, bodily functions, actions, and psychological characteristics (phenotype).

The genotype-phenotype relationship is the connection between the genetic information (genotype) and the observable traits (phenotype) of an organism. The genotype influences the phenotype, but the actual expression of traits can also be influenced by environmental factors, so some traits may be expressed differently in different environments.

With a temporary fluctuation of the Congo River’s water flow over a million years ago, one ape population became divided. Because neither species could swim, they were effectively separated, and the two populations encountered distinct environments.

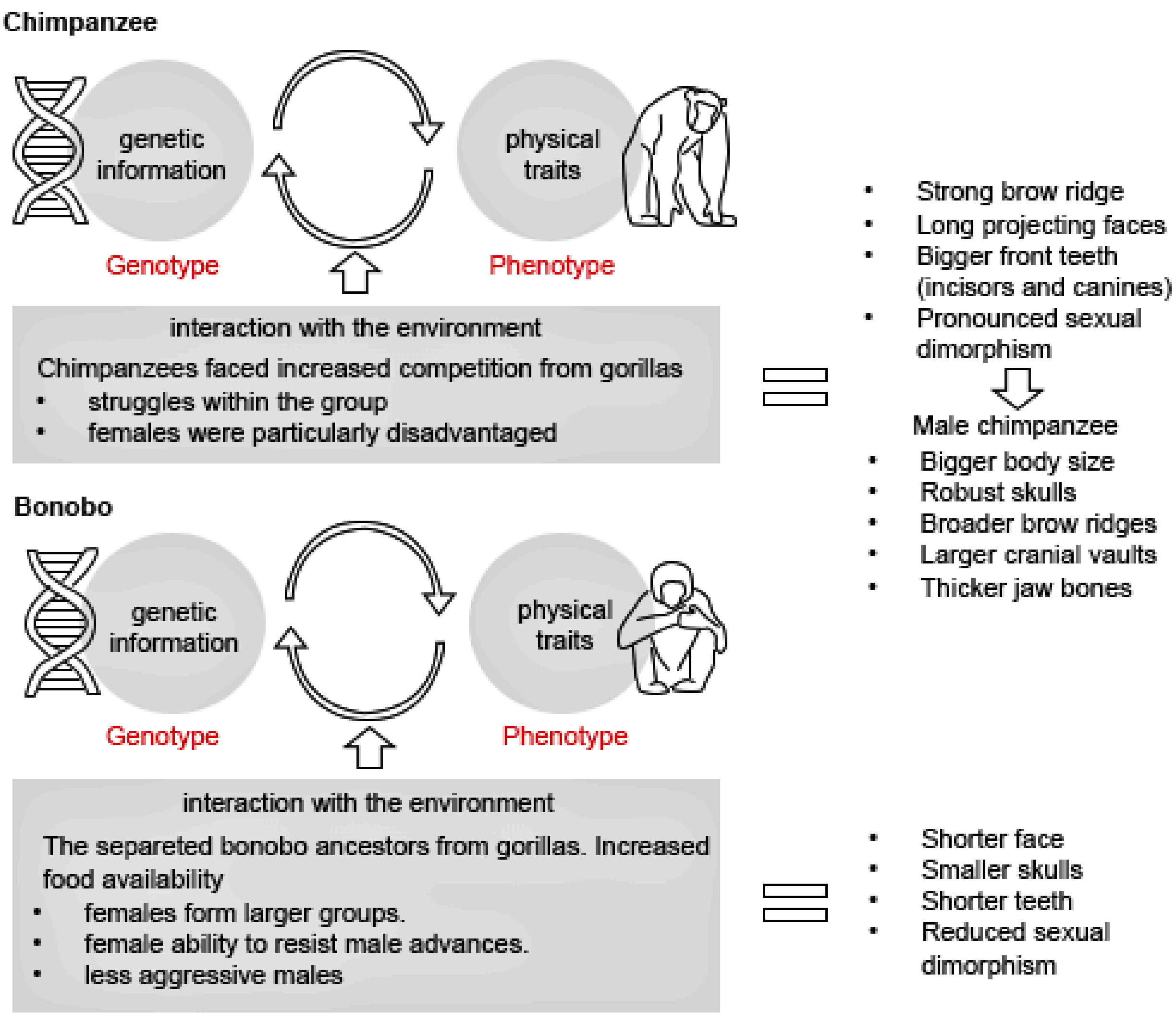
Hare (2011) suggests that the northern group, destined to become chimpanzees, faced more competition from gorillas for food. This led to intense competition within the group, particularly disadvantaging females who were easily dominated by males for both sex and resources.

In the southern region, where bonobos emerged, the story was different. The river acted as a natural barrier, protecting bonobo ancestors from gorillas. With more available food, females could form larger groups, build strong social bonds, and resist male advances more effectively. In this abundance, the less aggressive males, entering into alliances rather than seeking to assert themselves through brute force, were more likely to mate. On the south of the river, the more amicable apes thrived.

Consequently, it is believed that these animals, under Hare's perspective (2011), began to undergo a slower maturation process. Many domesticated species adapted by extending their development period, resulting in adults retaining juvenile characteristics. For instance, as Belyaev's foxes became more docile, their mental and physical traits resembled those of puppies rather than wild adults.

The same phenomenon probably occured in bonobos as they evolved from their ancestors. Changes in their physical features took place: faces became shorter, skulls reduced in size, sex differences diminished, and teeth shortened. This correlates with changes in behaviors, involving more play, grooming, and mating. The gentler generations also became more attuned to social cues. Through the gradual maturation process, they all acquired a common set of domesticated traits.

Figure 20 - Genotype & Phenotype



How does mate choice influence sexual dimorphism?

In *The Origin of Species*, Darwin carefully describes how evolution works, honing in on the process of natural selection. He also discusses other ways organisms can evolve, such through sex (sexual selection) or human influence (breeding). Basically, all these ways of changing and adapting can be summed up as the main forces driving biological evolution, and we call it selective pressure.

Sexual selection operates on traits that affect an individual's ability to obtain mates and reproduce. This process can lead to the evolution of traits that enhance an individual's reproductive success, even if those traits may not necessarily contribute to overall survival.

Darwin noted that sexual selection depends on the struggle between males to access females; and recognized two mechanisms of sexual selection: competition between members of the same sex (usually males) for access to mates; and mate choice where members of one sex (usually females) choose members of the opposite sex.

But why do female animals choose specific males instead of mating randomly or with the first male they meet? Even though it is not always apparent what benefits a female derives from picking a specific male, they still choose carefully. By picking specific males, females ensure that their babies inherit genes that make them more fit and better suited for survival. Females also avoid getting sick from parasites or diseases by choosing healthy males.

Males, on the other hand, tend to show off traits and behaviors that signal they can provide both direct and indirect benefits. This leads to a kind of "evolutionary dance" where females evolve preferences for these traits, and males evolve to showcase them.

In chimpanzees mate choice is influenced by both males and females, but the social structure is more hierarchical and is characterized by male dominance. Male chimpanzees compete for access to females, and females show preferences for dominant or high-ranking males.

In chimpanzees, physical traits such as size, strength, and even facial features are key factors in mate choice. Females generally prefer males with larger bodies and more pronounced sexual characteristics, as these traits can be indicators of genetic quality and reproductive fitness.

Whereas, in bonobos, both males and females play a role in mate choice, the social structure marked by female bonding and cooperation. Female bonobos maintain strong social bonds with their sons, and these bonds influence the male's social standing within the group. Mothers use their social connections to help their male offspring gain access to fertile females and navigate the complex social dynamics within the group.

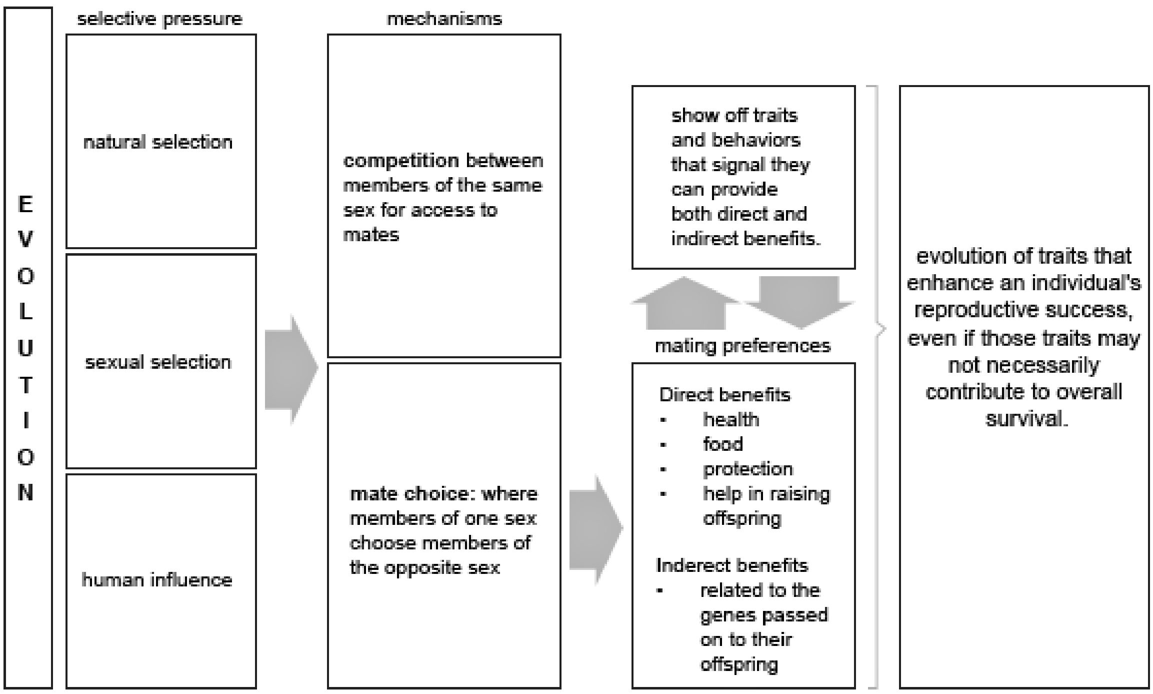
Bonobo females also show preference for males with particular physical characteristics such as size, strength, or facial features, but these preferences seem to be less significant compared to the social dynamics. Ultimately, female bonobos have agency in mate choice (reduced aggression may create an environment where females have more freedom in mate choice), and they actively seek out males who exhibit less aggressive behavior or who are more cooperative and affiliative.

This, however, does not mean that in bonobo culture, males have no sexual agency.

Recent research by Dr. Mouginot and her colleagues (2024) discovered that the most aggressive bonobos were also the ones who mated most frequently.

But what about humans? One could argue a complex interplay of social, cultural, and individual factors influences mate choice, and cultural norms vary widely across different societies. While traditional societies may have had more rigid gender roles in mate selection, contemporary societies often feature a more egalitarian approach. Both males and females have agency in mate selection.

Figure 21 - Mate choice & sexual dimorphism



Note: To kick off this discussion, you can ask your students: Is there evidence of more male or female-driven sexual selection in human cultures?

How do female coalitions in bonobos compare to male alliances in chimps?

The social structure of bonobos is female-centered, and some observers would say female-dominated. Females form strong coalitions by exchanging sexual favors for food and defense, ensuring the survival of themselves and their offspring (Boesch, C., Hohmann, G., & Marchant, L., 2002 - White, F. J., & Wood, K. D. 2007, - Furuichi, T., 2011 - Hare, B., Wobber, V., & Wrangham, R., 2012. - Hare, B., 2017).

In bonobo communities, the strongest social bonds are formed among females, although they also bond with males. In fact, a male's social status depends on his mother's position, to whom he remains closely bonded for her entire life.

The female coalitions not only enable the mitigation of conflicts but also the exertion of social influence within the group. Female bonobos have been observed to collectively dominate males and even mediate conflicts between males. Female coalitions also serve as a means of solidarity, especially in situations where resources are scarce.

On the other hand, chimpanzee groups are characterized by male dominance, where fully grown males are prominently dominant over females. They maintain their supremacy through aggression and violence, and it is rare for a female to dominate a fully grown male. Females live in overlapping home ranges within the territory but do not have strong bonds with other females or males.

Male chimpanzees often form alliances based on dominance hierarchies (among related males or those with similar social ranks). These alliances are crucial for maintaining access to resources such as food, territory, and mates. For example, when competing with other males for dominance and mating opportunities; or in territorial patrols the strength of alliances greatly influences their success in these interactions.

While both female bonobos' coalitions and male chimpanzees' alliances are critical for social cohesion and success within their respective species, they reflect the differing social dynamics and strategies that have evolved in response to their ecological and social environments.

Further Discussion Questions

- Is there a tendency between sexual dimorphism and the observed behavioral traits in each species?
- Does behavior impact the genetic level? Do genetics impact behavior?
- How do mate choice preferences in females relate to factors such as aggression, social bonding behaviors, and physical traits in each species?
- How do the cooperative strategies of female bonobo coalitions contrast with the competitive dynamics of male chimpanzee alliances?

Retrospective Take / Prospective Predictions

- **Past: 2 million years ago, do you think the bonobo-chimp ancestor was more bonobo or more chimp? How come?**

- **Future: Knowing what you now know, how might sexual dimorphism further evolve in the case of each of the 3 species?**

MEASURE OF ACCEPTANCE OF THE THEORY OF EVOLUTION (MATE)

Identifier given by your teacher:______________________________ Date:______________

Please respond to the statements below by marking Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), or Strongly Disagree (SD).

	SA	A	U	D	SD
Organisms existing today are the result of evolutionary processes that have occurred over millions of years. (1)	☐	☐	☐	☐	☐
The theory of evolution is incapable of being scientifically tested. (2)	☐	☐	☐	☐	☐
Modern humans are the product of evolutionary processes which have occurred over millions of years. (3)	☐	☐	☐	☐	☐
The theory of evolution is based on speculation and not valid scientific observation and testing. (4)	☐	☐	☐	☐	☐
Most scientists accept evolutionary theory to be a scientifically valid theory. (5)	☐	☐	☐	☐	☐
The available data are ambiguous as to whether evolution actually occurs. (6)	☐	☐	☐	☐	☐
The age of the earth is less than 20,000 years. (7)	☐	☐	☐	☐	☐
There is a significant body of data which supports evolutionary theory. (8)	☐	☐	☐	☐	☐
Organisms exist today in essentially the same form in which they always have. (9)	☐	☐	☐	☐	☐
Evolution is not a scientifically valid theory. (10)	☐	☐	☐	☐	☐
The age of the earth is at least 4 billion years. (11)	☐	☐	☐	☐	☐
Current evolutionary theory is the result of sound scientific research and methodology. (12)	☐	☐	☐	☐	☐
Evolutionary theory generates testable predictions with respect to the characteristics of life. (13)	☐	☐	☐	☐	☐
The theory of evolution cannot be correct since it disagrees with the Biblical account of creation. (14)	☐	☐	☐	☐	☐
Humans exist today in essentially the same form in which they always have. (15)	☐	☐	☐	☐	☐
Evolutionary theory is supported by factual, historical, and laboratory data. (16)	☐	☐	☐	☐	☐
Much of the scientific community doubts if evolution occurs. (22)	☐	☐	☐	☐	☐
The theory of evolution brings meaning to the diverse characteristics and behaviors observed in living forms. (18)	☐	☐	☐	☐	☐
With few exceptions, organisms on earth came into existence at about the same time. (19)	☐	☐	☐	☐	☐
Evolution is a scientifically valid theory. (20)	☐	☐	☐	☐	☐

NEXT GENERATION SCIENCE STANDARDS (NGSS)

NGSS Science and Engineering Practices:

- Asking Questions and Defining Problems: Students can formulate questions about the differences in cranial morphology between males and females in humans, bonobos, and chimpanzees, and how these differences might relate to gender-specific behaviors.
- Planning and Carrying Out Investigations: Students will design and conduct experiments to measure and analyze cranial features and observe behaviors, ensuring that their methodologies are systematic and reliable.
- Analyzing and Interpreting Data: Students will collect and analyze data on cranial measurements and behavioral observations to identify patterns and draw conclusions about sexual dimorphism and gender-specific behaviors across the species.
- Constructing Explanations and Designing Solutions: Based on their data analysis, students will develop explanations for observed differences in cranial morphology and behaviors, considering factors such as evolutionary adaptation and social dynamics.
- Engaging in Argument from Evidence: Students will present and defend their findings and interpretations using scientific evidence, engaging in discussions and debates about the significance of their results.

NGSS Crosscutting Concepts:

- Patterns: Students will identify patterns in cranial measurements and behaviors across different species and genders, recognizing similarities and differences.
- Cause and Effect: Students will investigate potential causal relationships between cranial morphology and gender-specific behaviors, considering factors such as hormonal influences and evolutionary pressures.
- Systems and System Models: Students will explore how cranial features and behaviors are components of larger biological systems, considering the interconnectedness of anatomy, physiology, and behavior.
- Stability and Change: Students will analyze how cranial sexual dimorphism and gender-specific behaviors may change over evolutionary time scales and in response to environmental factors.

NGSS Disciplinary Core Ideas:

- Life Sciences: Students will explore concepts related to biological evolution, including how natural selection can shape morphological and behavioral traits in response to ecological pressures.
- Earth and Human Activity: Students will consider the impact of human activities on the behavior and morphology of species like bonobos and chimpanzees, highlighting the interconnectedness of human and non-human ecosystems.

NGSS Performance Expectations:

- HS-LS4-1: Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.
- HS-LS2-8: Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

LAB ASSESSMENT

Name: ______________________________ Date: ______________

1. (T o F) Sexual dimorphism refers to the differences in reproductive organs between males and females.
2. (T o F) Sexual dismorphism refers to differences in physical characteristics between males and females of the same species.
3. (T o F) The study of sexual dimorphism and behaviors can provide insights into evolutionary biology.

4. Evolution is:
   a. One animal turning into a completely different animal
   b. Change in a habitat over time
   c. Trait that enhances survival
   d. Gradual change in a species over a long time

5. Which species exhibits the highest degree of sexual dimorphism in cranial features?
   a. Humans
   b. Bonobos
   c. Chimpanzees
   d. None of the above

Use the following data to answer questions 6 to 9.

In a study conducted at a chimpanzee sanctuary, researchers measured the canine teeth of a group of adult male and female chimpanzees. The measurements were taken from the tip of the canine to the gum line. The data collected are as follows:

	Canine tooth lengths						
Male Chimpanzees	25	27	28	26	29	31	30
Female Chimpanzees	22	23	21	24	20	22	25

6. Calculate the mean canine tooth length for male chimpanzees and female chimpanzees separately.

7. Based on the data, do male chimpanzees tend to have longer canine teeth compared to female chimpanzees? Explain your reasoning.

8. Would you consider the difference in canine tooth lengths between male and female chimpanzees as an example of sexual dimorphism? Why or why not?

9. Discuss the potential evolutionary reasons behind the observed sexual dimorphism in canine tooth lengths in chimpanzees. How might differences in canine teeth contribute to mating strategies or social behaviors within chimpanzee populations?

10. Which species among humans, bonobos, and chimpanzees exhibit higher levels of male aggression?

a. Humans
b. Bonobos
c. Chimpanzees
d. All species exhibit similar levels

11. Gender roles primarily emerge from:
a. Genetic factors
b. Cultural influences
c. Environmental factors
d. All of the above

12. Which mechanism of evolution is primarily responsible for the development of elaborate physical traits in males, such as antlers in deer or elaborate plumage in birds?

a. Sexual selection
b. Natural selection
c. Genetic drift
d. Mutation

13. How does sexual dimorphism contribute to the concept of reproductive success in evolutionary biology?

a. By enhancing an individual's ability to compete for mates.
b. By increasing survival rates in offspring.
c. By reducing the risk of predation.
d. None of the above.

14. The phenomenon where individuals preferentially choose mates based on certain traits, leading to sexual dimorphism, is known as:

a. Sexual aggression
b. Sexual selection
c. Gender bias
d. Mate coercion

15. Mate choice, a form of sexual selection, is often driven by:
a. Physical attractiveness
b. Resources and territory
c. Genetic compatibility
d. All of the above

16. Explain how sexual dimorphism in the cranial and mandible features can be influenced by behaviors such as aggression and sharing food. Provide examples from human, bonobo, or chimpanzee behavior.

17. Describe the relationship between behavior and genetics concerning gender roles in humans, bonobos, and chimpanzees. How might genetic predispositions influence behavioral differences between males and females within these species?

18. Explore the possible evolutionary advantages of behaviors such as aggression and sharing food in humans, bonobos, and chimpanzees. How might these behaviors contribute to survival and reproductive success within each species?

19. How do cultural factors influence gender-specific behaviors in humans compared to bonobos and chimpanzees? Consider the role of social structures, environmental factors, and learned behaviors in shaping gender roles within these species.

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