EXPLORATIONS LAB AND ACTIVITIES MANUAL

Explorations

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Explorations Lab and Activities Manual

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TABLE OF CONTENTS

The Explorations Biological Anthropology Lab Manual includes 1-4 labs/activities for each of the sixteen chapters and three appendices in Explorations. Each lab/activity includes:

- Learning objectives
- List of required supplies
- Instructions for faculty
- Estimated duration
- Student worksheets
- Reference to the corresponding Explorations chapter
- Consistent format and style

Many labs are designed to be easily adapted for distance learning courses.

Index

Glossary

CHAPTER OVERVIEW

1: Introduction to Biological Anthropology

Learning Objectives

- Recognize and differentiate scientific fact from different ways of knowing.
- Articulate the importance of differentiating between belief and knowledge without discounting alternative ways of knowing or acquiring beliefs

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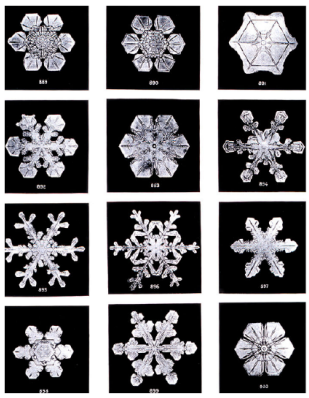
1.1: Knowing and Believing

Knowing and Believing

Format: In-person or online



Snowflakes by Wilson Bentley (1902)

Authors: Sydney Quinn Chizmeshya & Katherine E. Brent

Time needed: 20-40 minutes

Supplies Needed

- Activity sheet for each student (attached), or statements projected on a screen for the class to see
- Writing utensil
- Textbook

Introduction

The learning goal of this activity is for students to become comfortable recognizing and differentiating scientific fact from different ways of knowing. Additionally, students should acknowledge the importance of differentiating between belief and knowledge without discounting alternative ways of knowing or acquiring beliefs in hopes of maintaining cultural relativity.

Procedure

- Distribute one activity page to each student, or project the statements listed below onto a screen. This activity can be done individually, in groups, or as a class. There is also an opportunity to start the activity individually, and to consequently take up answers in a pair-and-share or class discussion.
- Before beginning the activity, students should write the definitions of ‘knowledge’ and ‘belief’ in their own words. Subsequently, they should compare these with the definitions put forth in the textbook. Putting class concepts into one’s own words helps to solidify concepts for students.
- Next, students should be instructed to read each of the following statements and indicate on the activity sheet, adjacent to each example phrase, whether the statement reflects knowledge or belief.

Statements

1. The sun rises in the East and sets in the West.
2. All living things need water to survive.
3. God is real.
4. No two snowflakes are identical.
5. Lord of the Flies is the best novel ever written.
6. Ottawa is the capital of Canada.
7. The Mona Lisa is the most beautiful painting in the world.
8. Broccoli is delicious.
9. Carbon monoxide is dangerous to humans in large quantities.
10. Dr. G is the best professor.

- After responding to the given statements, each student should write a statement of belief and a statement of knowledge on the activity sheet.
- Once students have labelled each statement accordingly, and written their own statements, discuss in groups, or as a class.
- Ensure that you bring forth any discussions as to why students labelled statements as belief or knowledge into a classroom discussion. Students should use the textbook definitions of “knowledge” and “belief” to aid in justifying their answer.
- Instructors can further engage the class by discussing why it is important for anthropologists to be cognizant of both knowledge and beliefs-- this can introduce the idea of anthropologists as both scientists and cultural relativists.
- Additionally, the idea that knowledge and beliefs can sometimes become ‘tangled’ should be addressed. For instance, it is not uncommon to see scientific knowledge (e.g. that climate change is real) as a belief, or a belief (e.g. that race is biologically founded) as knowledge. As such, differentiation is important.

Statement Answer Key

Statement	**Belief or Knowledge?**
The sun rises in the East and sets in the West.	Knowledge
All living things need water to survive.	Knowledge
God is real.	Belief
No two snowflakes are identical.	Knowledge
Lord of the Flies is the best novel ever written.	Belief
Ottawa is the capital of Canada.	Knowledge
The Mona Lisa is the most beautiful painting in the world.	Belief
Broccoli is delicious.	Belief
Carbon monoxide is dangerous to humans in large quantities.	Knowledge
Dr. G is the best professor.	Belief
Write your own statement of belief.	*To be evaluated*
Write your own statement of knowledge.	*To be evaluated*

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

This activity could be using various online programs such as Quizlet, Kahoot, or as an activity completed and submitted through the school’s respective online Learning ManagementSystem. Creating an online discussion board to articulate the reasoning behind answers as well as follow up questions is highly recommended. This activity may also be used as an iClicker activity.

References

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. “Chapter 1: Introduction to Biological Anthropology” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

SnowflakesWilsonBentley by Wilson Bentley is marked as public domain.

1.2: Icebreaker Science

Icebreaker Science

Format: In-person

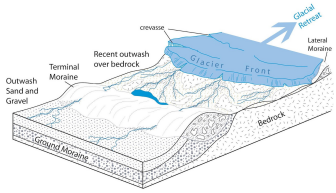


Illustration of a retreating glacier.

Author: Keith Chan

Time needed: 60 minutes

Learning Objectives

- Experience the scientific process
- Interact with classmates
- Explore statistical sampling and analysis

Supplies Needed

- Writing supplies

Readings

-

Introduction

The first day of lab sets expectations for the rest of the course. A lot has to be accomplished: attendance, the syllabus, a learning activity, and becoming familiar with each other. This activity addresses the latter two goals in a way that also uses the scientific method and statistical thinking.

Students are given each question ahead of time so they can consider their own answer as well as what the class is like as a group. After this step, students move around the classroom and chat in different groups based on having something in common. When all of the questions have been explored, the instructor can review the results of each item to learn whether the students' expectations were met or not.

Steps

- Ask students to write what percent of the class fit each of the categories listed on the Categories sheet. This is the hypothesis part of the activity.
- For each category, students move to a certain part of the class. For example, students who have been on a roller coaster stand to the left and those who have not stand to the right.
- Give students a minute to meet each other in their group for each category.
- Record the percent of students on each side for each category. This is the observation part of the activity.
- After the categories have all been surveyed, have the class return to their seats.
- Go through each category and ask students for their impressions. Did they get close or not?

Conclusion or Review Questions

This activity got students moving and interacting each other while exploring the scientific process of hypothesis testing. Here are a few questions to conclude the activity:

- Are these results representative of the country? The city? The school? Why or why not? This question can segue into a discussion of bias and sampling methods.
- Which hypotheses could be considered "close enough" to the results? This can lead to an introduction to statistical inference and the standards used in science.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Students could form breakout rooms for each category, raise their hands, or respond in chat.

Tips and Suggestions

Come up with your own questions related to your school or community. Avoid questions that can be too personal (e.g., are you parents still together or not?) or involve knowledge that is too specific (e.g, did you like the last season of Game of Thrones?).

Image Attributions

Thornberry-Ehrlich, Trish L., Colorado State University. (2017). Glacier Features [Illustration]. United States Public Domain Mark 1.0. https://flic.kr/p/Rji5E7.

Icebreaker Science Categories

Ridden a roller coaster or not
Is a dog or cat person
Have been to Europe or not
Is a morning or night person
Like to go jogging or not
Have eaten an insect or not
Have done karaoke or not
Have their birthday in the first or second half of the year
Like to eat seafood or not
Like group work or solo work

1.3: Science and Belief- Just Because We Can, Doesn't Always Mean We Should

Science and Belief: Just Because We Can, Doesn't Always Mean We Should.

Format: In-person or online (discussion or lab activity)

Image Caption: International Symbol for Deafness and Hearing Loss

Author: Anne E. Pfister, PhD

Time needed: 45-75 minutes

Learning Objectives

- Distinguish between science and belief
- Apply anthropological theories and methods to understanding real-world issue

Supplies Needed

- Short readings (provided)
- Worksheet (provided)
- Space for discussion (if in-person)
- Discussion board (if online)

Readings

-
- Sprigs, M. 2002. Lesbian couple create a child who is deaf like them. *Journal of Medical Ethic*s. 28:283.
- Ives, James. 2020. Researchers Treat Deafness with Gene Therapy. News *Medical Life Sciences*.

Introduction

Chapter two author, Jonathan Marks (2017) presents anthropology as the "science of mediation". This lesson and activity invite Marks's style of intellectual dialogue, encouraging us to find nuanced connections between some seemingly contradictory concepts. In this lesson, we contemplate two different relational concepts fundamental to the anthropological study of human beings as a species.

Students read two articles that approach deafness from different perspectives and analyze the role of culture and biology with regard to human conditions and diversity as well as the role of science and belief in bio-medical intervention (and other scientific pursuits).

Steps

- Introduce (or review) the properties of science and the properties of belief systems. Remind students that both science and belief systems are valid ways of exploring and evaluating phenomena; they are systems we use to understand the world around us. Belief systems take many forms (ethics, morals, philosophy, religion and laws, for example) and science comes from a specific historical context which then spread on a global scale.
- Distribute the worksheet and the readings listed above. Give students approximately 20-30 minutes to read both articles/summaries (they are reading for big ideas, not doing close readings).
- Discuss students' reactions to the articles.
- Ask students what big ideas are in tension. How can these dyadic concepts be "mediated" through anthropological approaches?

- Dyadic concepts to discuss might include: Culture and biology; science and belief; nature and nurture; ontology and epistemology.

Takeaway Ideas and Points for Review:

All humans use science AND belief systems to explore the world in our attempt to understand it. Sometimes we have the science to ameliorate problems, but our belief system (ethics, morals, laws) dictate whether (and how) we put science into action (or not!). Think about cloning, for example. We have advanced science capable of cloning our pets (see Brogan, 2008 article in the For Further Exploration below). Does that mean we should? What about cloning your little brother?

Therein lies the irony of the presentation of these two articles together. Gene therapy works only for people with genetically inherited deafness (i.e. folks that are born into deaf families). People are born deaf or deafened for many reasons (genetic causes account for about half of childhood cases, according to the CDC). More importantly, many deaf people, like the couple in one of the articles, do not view deafness as a disability and many people who approach deafness from a deaf cultural perspective do not view deafness as a loss but often as gain (see Bauman et. al., 2014 article in the For Further Exploration below). In fact, some ethnographic research suggests that deaf families (i.e. families with deaf relatives) are the least likely to seek medical intervention (like gene therapy) because they prioritize the shared cultural and linguistic experience in deaf communities and through the use of sign language (see readings in the For Further Exploration section below for examples and discussion).

- Important: Pointing out this irony does not suggest that either approach is wrong. Again, anthropological theories and methods help us embrace that which is apparently contradictory and "mediate" common ground for more holistic understandings of complex issues like deafness.
- A nuanced approach to deafness –one that acknowledges the connections between culture/biology and science/belief – might better focus resources and programs for deaf people and their families.
- Other dyadic concepts to consider: nature & nurture; ontology & epistemology; organic & synthetic; individual & group; extraordinary & mundane

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

Bauman, Dirksen and Murray, Joseph. 2014. An Introduction to Deaf Gain. *Psychology Today*.

Brogan, Jason. 2008. The Real Reason You Shouldn't Clone Your Dog. *Smithsonian Magazine*.

Centers for Disease Control and Prevention. 2020. Hearing Loss in Children, *National Center on Birth Defects and Developmental Disabilities*.

Cooper, Rachel. 2007. Can it be a Good Thing to be Deaf? *The Journal of Medicine and Philosophy.* 32(6):563-583.

Kusters, Annelies. 2015. *Deaf Space in Adamorobe: An Ethnographic Study in a Village in Ghana*. Gallaudet University Press.

Mullin, Emily. 2020. The End of Deafness: Gene Therapy Could End Deafness. Should it? *Future Human*.

Pfister, Anne E. 2017. Forbidden Signs: Language Socialization and Therapeutic Approaches to Language in Mexico. *Ethos.* 45(1):139-161.

Image Attributions

International Symbol for Deafness and Hearing Loss by the State of Rhode Island is in the public domain.

References

Marks, Jonathan. 2017. *The Alternative Introduction to Biological Anthropology*, 2nd Edition. Oxford University Press.

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. "Chapter 1: Introduction to Biological Anthropology" In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Science and Belief Worksheet

Embracing Anthropology as a “science of mediation”

Jonathan Marks (2017) presents anthropology as the “science of mediation”. This lesson and activity pursue intellectual dialogue, encouraging us to find nuanced connections between some seemingly-contradictory concepts that inform our understanding of what it means to be human.

In this lesson, we contemplate two different relational concepts fundamental to the anthropological study of human beings as a species.

Step 1

Using the chart below, jot down some adjectives that describe the characteristics of science and belief (you may also use associated words, or those that can be used interchangeably).

SCIENCE	BELIEF

Step 2

Now, do the same for biology and culture. Jot down some adjectives that describe the characteristics of each.

BIOLOGY	CULTURE

Step 3

Now, read the two short articles. Don’t get bogged down by too many details. Instead, read so you understand the general idea behind the two very different approaches to deafness. Then, review the discussion questions below and prepare your thoughts for the discussion. You may wish to jot down your thoughts ahead of the discussion.

Questions for Discussion:

1. Prior to reading these articles, did you think about deafness as being primarily biological or cultural?
2. Do either or both articles consider deafness from a predominantly biological approach?
3. Do either or both articles approach deafness from more of a cultural understanding?
4. What are the roles of science and belief in each of the articles?
5. Did reading these articles and discussing them change any of your ideas about science/belief and culture/biology? About approaches to deafness?
6. How can anthropological methods and theories help inform our understandings of deafness and other conditions/statuses/phenomena?
7. What other seemingly-contradictory concepts do these articles underscore?
8. Do you perceive any irony in the contrast between these two articles?

> **Note**
>
> Review the Take-away Ideas Conclusions document once instructed to do so.

Take-away Ideas and Conclusions:

- All humans use science AND belief systems to explore the world and attempt to understand it. Sometimes we have the science to ameliorate problems, but our belief system (ethics, morals, laws) dictate whether (and how) we put science into action (or not!). Think about cloning, for example. We have advanced science capable of cloning our pets (see article below). Does that mean we should? What about cloning your little brother?
- Therein lies the irony of the presentation of these two articles together. Gene therapy works only for people with genetically inherited deafness (i.e. folks that are born into deaf families). People are born deaf or deafened for many reasons (genetic causes account for about half of childhood cases, according to the CDC). More importantly, many deaf people, like the couple in one of the articles, do not view deafness as a disability and many people who approach deafness from a deaf cultural perspective do not view deafness as a *loss* but often as *gain* (see article below). In fact, some ethnographic research suggests that deaf families

(i.e. families with deaf relatives) are the least likely to seek medical intervention (like gene therapy) because they seek the shared cultural and linguistic experience in deaf communities and through the use of sign language (see articles below).
    - **Important**: Pointing out this irony does not suggest that either approach is wrong. Anthropological theories and methods help us embrace that which is apparently contradictory and "mediate" common ground for more holistic understandings of complex issues like deafness.
    - A nuanced approach to deafness –one that acknowledges the connections between culture/biology and science/belief – might better focus resources and programs for deaf people and their families.
- Other dyadic concepts to consider: nature & nurture; ontology & epistemology; organic & synthetic; individual & group; extraordinary & mundane

References

Marks, Jonathan. 2017. *The Alternative Introduction to Biological Anthropology*, 2nd Edition. Oxford University Press.

Further Reading:

- Bauman, Dirksen and Murray, Joseph. 2014. An Introduction to Deaf Gain. *Psychology Today*.
- Brogan, Jason. 2008. The Real Reason You Shouldn't Clone Your Dog. *Smithsonian Magazine*.
- Centers for Disease Control and Prevention. 2020. Hearing Loss in Children, *National Center on Birth Defects and Developmental Disabilities*.
- Cooper, Rachel. 2007. Can it be a Good Thing to be Deaf? *The Journal of Medicine and Philosophy.* 32(6):563-583.
- Kusters, Annelies. 2015. *Deaf Space in Adamorobe: An Ethnographic Study in a Village in Ghana*. Gallaudet University Press.
- Mullin, Emily. 2020. The End of Deafness: Gene Therapy Could End Deafness. Should it? *Future Human*.
-
- Pfister, Anne E. 2017. Forbidden Signs: Language Socialization and Therapeutic Approaches to Language in Mexico. *Ethos.* 45(1):139-161.

CHAPTER OVERVIEW

2: Evolution

Learning Objectives

- Operationalize questions using the scientific method.
- Evaluate methods for scientific study of human phenomena.
- Distinguish between science and dogma.

Thumbnail: The alchemist by Carl Spitzweg

2.1: The Scientific Method- Converting Curiosity into Study

The Scientific Method: Converting Curiosity into Study

Format: In-person or online (discussion or lab activity)

Author: Anne E. Pfister, PhD

Time needed: 30-40 minutes

Supplies Needed

- Worksheet (provided)
- Vides (links provided)
- Space for discussion (if in-person)
- Discussion board (if online)

Readings

-
-

Introduction

During this activity, students learn to operationalize ideas and form a hypothetical research design using the scientific method. This introductory activity is designed to get students thinking about topics that interest them that fall within the realm of anthropological study. Most of all, it helps them identify what topics can be approached scientifically and which cannot.

Steps

1. Introduce the concepts of science and belief, explaining that humans use both systems to learn about the world. Explain that science is self-correcting while dogma is unwavering. Discuss examples (i.e. we have the science and technology to clone animals, should we clone humans? This illustrates how science depends on ethics, a belief system. Beliefs cannot be scientifically 'tested' while natural phenomena can be).
2. Review the steps of the scientific method and the assumptions of science introduced by Jonathan Marks in the beginning of Chapter Two: Evolution in *Explorations*.
3. View the short video Turtles and Snakes by Mark Rober to underscore how nearly any idea or curiosity can be converted into scientific study using the tenants of the scientific method: https://www.youtube.com/watch?feature=player_embedded&v=k-Fp7flAWMA#!
4. Distribute worksheets and have students work independently (or in pairs).
5. (Optional) ask students to share the research topics they brainstormed for the class discussion.
6. Discuss take-away ideas with the class.

Takeaway Ideas and Points for Review:

- All humans use science and belief systems to explore the world and create theories about it.
- Science is a specific way of investigating the world. Scientists use the scientific method because it helps us operationalize ideas and standardize approaches to answering difficult questions and creating theories about our observations.
- Science is self-correcting – as new (and potentially contradictory) data are introduced, theories are amended or improved upon. Dogma is static and does not change.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Tips and Suggestions

This lab activity and discussion help students and professors identify the interests of individuals in the class. It also motivates students to know that virtually anything they are curious about can be operationalized into a research project using the scientific method.

For Further Exploration

The Scientific Method, Sprouts: https://www.youtube.com/watch?v=yi0hwFDQTSQ&vl=en

Science vs. Dogma, Nature: https://www.nature.com/articles/23307

Image Attributions

The alchemist by Carl Spitzweg is in the public domain

References

Nelson, Katie, Lara Braff, Beth Shook, and Kelsie Aguilera. 2019. “Chapter 1: Introduction to Biological Anthropology” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Marks, Jonathan. 2019. “Evolution” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

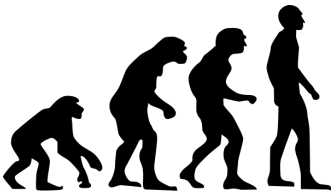
The Scientific Method: Converting Curiosity into Study Worksheet

1. How does the epistemology of science differ from other ways of knowing about the world?
2. Write two (or more) questions (related to humans/anthropology) – one that COULD be investigated scientifically and one that CANNOT be tested scientifically.
   a.
   b.
3. Design a mock study using some of the steps of the scientific method below to answer a provocative question you have about biological anthropology.
   a. Identify the question or the potential relationship between two or more observable phenomena:
   b. Formulate hypotheses about expected outcomes between variables, based on existing theory:
   c. What primary methods would you use to collect observations pertaining to the question:
   d. What aspects of the study are holistic? In other words, which other sub-fields of anthropology might be interested in the results of your study? Why?

2.2: Misconceptions about Evolution

Misconceptions About Evolution

Format: In-person or online



A commonly used illustration for human evolution that suggests evolution is linear and modern humans are the crowning achievement of that process.

Author: Beth Shook

Source: Inspired by Misconception Quizzes Teach.Genetics.utah.edu. Genetic Science Learning Center. University of Utah

Time needed: 15-20 minutes

Learning Objectives

- Identify and clarify misconceptions surrounding evolution and evolutionary forces
- Review animal examples illustrating how evolution works

Supplies Needed

- Worksheet (provided)
- Access to the internet to show a video from learn.genetics.utah.edu

Readings

-

Introduction

There are many misconceptions about what evolution is and how it works via natural selection to cause changes in species. This brief activity helps students identify any misconceptions they may hold and then helps them to achieve a more accurate understanding of evolution. To do so, they will view a short video and answer a series of questions.

Steps

- Students will individually complete the provided worksheet by checking the statements that they believe to be true.
- Instructors will show the five-minute video "Things You May Not Know About Evolution" (https://learn.genetics.utah.edu/cont...misconceptions).
- Students will check their answers as they watch the video.

Conclusion

The instructor should lead a brief discussion afterwards to see what the most common misconceptions in the class were (based on the most missed questions) and clarify any questions that students may have from the worksheet or film.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This worksheet can be provided for students to complete asynchronously and they can watch the video either on their own or in a synchronous class section. The later option would allow for a brief instructor-led discussion.

For Further Exploration

References

Marks, Jonathan. 2019. “Chapter 2: Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. CC BY-NC http://explorations.americananthro.org/

“Misconception Quizzes.” 2011. Teach.Genetics.utah.edu. Genetic Science Learning Center. University of Utah. https://teach.genetics.utah.edu/content/evolution/files/misconceptionquiz_key.pdf

“Things You May Not Know About Evolution” 2011. Learn.Genetics.utah.edu. Genetic Science Learning Center. University of Utah. https://learn.genetics.utah.edu/content/evolution/misconceptions

Image Attributions

Human evolution by Tkgd2007 is used under a CC BY-SA 3.0 License.

Misconceptions About Evolution Worksheet

For each number, check the statement that is true.

1. ☐ Organisms are perfectly structured for their environment.

   ☐ Organisms have many traits that are not perfectly structured, but function well enough to give an organism a competitive advantage.

2. ☐ Natural selection favors the development of new traits.

   ☐ Natural selection often modifies existing structures but must work within the limits of what is available.

3. ☐ Evolution is climbing a ladder towards perfection.

   ☐ Evolution may cause the loss of beneficial or complex traits.

4. ☐ Some species and some genes remain largely unchanged over millions of years.

   ☐ Natural selection always favors change.

5. True or False? The process of natural selection can only work on structures that are in use.

   ☐ True.

   ☐ False.

6. ☐ Evolution is a theory, which is a well substantiated explanation for observable facts.

   ☐ Evolution is a theory, which means it is a guess.

7. ☐ In order to accept evolution as a valid explanation, you cannot believe in God.

   ☐ The theory of evolution and religion can be compatible.

8. ☐ The complexity of an organism determines the size of its genome.

   ☐ The complexity of an organism has no correlation with the size of its genome.

9. ☐ Humans are the ultimate achievement of evolution.

☐ Humans are less complex than other organisms in many ways.

10. ☐ Evolutionary patterns look like the branches on a tree.

    ☐ Evolution is linear.

CHAPTER OVERVIEW

3: Molecular Biology and Genetics

Learning Objectives

- Observe how blood agglutinates in the presence of foreign antibodies
- Explain how different genotypes can result in the same phenotype
- Explain the concepts of dominant, co-dominant, and recessive traits
- Use Mendelian inheritance patterns to draw Punnett squares and assess parentage
- Assess whether or not blood types function as a Mendelian trait

Thumbnail: Human blood cells photographed by an electron microscope.

3.1: Blood Typing Lab

Blood Typing

Format: In-person or online

Authors: Katherine E. Brent and Sydney Quinn Chizmeshya

Source: Modified from Classroom Activity on Antibodies. *Oxford Sparks.*

Time needed: 30-40 minutes total. 15-20 minutes for the activity; 15-20 minutes for the reflection questions

Supplies Needed

- Milk, vinegar, water
- Red gel food coloring
- Eyedroppers or pipettes (5 per group)
- Permanent marker
- Toothpicks or stirrers (6 per group)
- Small containers or sealable test tubes (5 per group)
- Blood typing test plate (attached) laminated or placed in a plastic sheet protector (1 per group)
- Student worksheet (attached)

Readings

-

Introduction

In this lab students will perform a blood type test, also called an agglutination assay, on the simulated blood of three individuals. They will observe the agglutination reaction, and determine the blood types of three individuals. Subsequently, students will answer reflection questions about the observations they made during the experiment, as well as consider the inheritance patterns for ABO blood types and what characteristics of this trait are regarded as “Mendelian”.

Steps

- Prepare three solutions: vinegar with food coloring, milk with food coloring, and water with food coloring. Slowly add food coloring little by little to ensure that the dye does not coagulate the substance.
- Each group of students should be given the following lab kit materials:
  - Labelled test tubes or small containers:
    - Individual #1: Dyed vinegar (this will simulate Type A blood)
    - Individual #2: Dyed milk (this will simulate Type B blood)
    - Individual #3: Dyed water (this will simulate Type O blood)
    - Anti-A Serum: Milk
    - Anti-B Serum: Vinegar
  - Five eyedroppers or pipettes
  - Permanent marker
  - Six toothpicks or stirrers
  - Blood Typing Test Plate (attached) laminated or placed in a plastic sheet protector (1 per group)
  - Student worksheets
- Students should use the instructions on their worksheet to complete the lab. When students perform the experiment, they must use each pipette for only the substance it is intended to be used for, as cross-contamination may provide false coagulations.
- Using the pipette for Individual #1, they will pipette several drops of Individual #1’s blood sample into the circles comprising the first column of the laminated blood typing test plate. Individual #2’s sample should be pipetted into to the second column, and Individual #3’s sample pipetted into the third column.
- Using the pipette for Anti-A Serum, pipette several drops of Anti-A serum into each blood sample in the first row of the test plate. Using the pipette for Anti-B Serum, pipette several drops of Anti-B serum into each blood sample in the second row of the test plate.

- Students will stir each sample using a different toothpick for each of the six samples.
- Students will observe each sample to see if it has coagulated (agglutinated) or not, and determine the three individuals' blood types based on the results.
- Students will complete the reflection questions on their worksheet.

Conclusion

Students will practice observation and problem solving through this lab, as well as review key concepts about Mendelian inheritance and blood typing. Reflection questions are provided on the student worksheet and instructors are encouraged to review some or all of these questions as a class afterwards.

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

With clear directions most students could create the artificial blood and serums, as well as complete the experiment, in their home. Instructors could also record a short video showing the experiment for students to watch and reflect on at home.

For Further Exploration

ThePenguinProf. Blood Types: ABO and Rh (with donuts and sprinkles!) https://www.youtube.com/watch?v=L06TJTMVkBo

Wake, Carol. 2005. "ABO/Rh Blood Typing Model: A Problem-Solving Activity." *The American Biology Teacher* 67 (3): 158-162.

References

Arnold, Savittree Rochanasmita, Tussatrin Kruatong, Chanyah Dahsah, and Duongdearn Suwanjinda. 2012. "The Classroom-Friendly ABO Blood Types Kit: Blood Agglutination

Simulation." *Journal of Biological Education* 46 (1): 45-51. https://doi.org/10.1080/00219266.2011.556750

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology,* edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

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Blood typing test plate by Katherine E. Brent and Sydney Quinn Chizmeshya original to Explorations Lab and Activities Manual is under a CC BY-NC 4.0 License.

Blood Typing: Worksheet

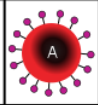
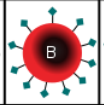
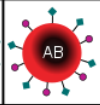
Background

This lab explores the concepts of Mendelian inheritance using the ABO Blood Group System as an example. Please review the corresponding sections: "Mendelian Genetics" and "Example of Mendelian Inheritance: The ABO Blood Group System" in *Explorations* Chapter 3: Molecular Biology and Genetics, which will provide the background information to complete the lab exercise.

In this lab, you will be performing a blood type test (agglutination assay) on the simulated blood of three individuals. Subsequently, you will answer reflection questions about the observations you made during the experiment.

As a reminder:

- Blood types in the ABO Blood Group System are A, B, O, and AB.
- A and B alleles are dominant over the O allele, and are codominant with each other. This is because possessing the A or B allele always leads to the production of the corresponding antigen.

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in red blood cell	A antigen	B antigen	 A and B antigens	None

Blood Types Table

- **Type A blood** with A antigens will coagulate (agglutinate) when they come in contact with anti-A serum (antibodies), but produce anti-B antibodies in a living person, so will not coagulate with anti-B serum.
- **Type B blood** with B antigens will coagulate (agglutinate) when they come in contact with anti-B serum (antibodies), but produce anti-A antibodies in a living person, so will not coagulate with anti-A serum.
- **Type AB blood** has both A and B antigens, and will coagulate (agglutinate) when they come in contact with either anti-A or anti-B serum (antibodies). These individuals do not produce anti-A or anti-B antibodies.
- **Type O blood** produces both anti-A and anti-B antibodies, so it will not coagulate with Anti-A or Anti-B Serum.

Lab Kit Materials

- Labelled test tubes or small containers:
  - Individual #1 Blood Sample
  - Individual #2 Blood Sample
  - Individual #3 Blood Sample
  - Anti-A Serum
  - Anti-B Serum
- Five eyedroppers or pipettes
- Permanent marker
- Six toothpicks or stirrers
- Blood Typing Test Plate laminated or placed in a plastic sheet protector

Instructions

1. Using the permanent marker, label each of your five pipettes with one of the substance names (e.g. Individual #1, Anti-A serum). When you perform the experiment, you must ensure that you use each pipette for only the substance it is intended to be used for, as cross-contamination may provide false coagulations.
2. Using the pipette for Individual #1, pipette several drops of Individual #1's blood sample into the circles comprising the first column of the blood typing test plate. Individual #2's sample should be pipetted into to the second column, and Individual #3's sample pipetted into the third column.
3. Using the pipette for Anti-A Serum, pipette several drops of Anti-A serum into each blood sample in the first row of the test plate. Using the pipette for Anti-B Serum, pipette several drops of Anti-B serum into each blood sample in the second row of the test plate.
4. Using a different toothpick for each of the six samples, stir each sample.
5. Observe each sample to see if it has coagulated (agglutinated) or not.

Reflection Questions

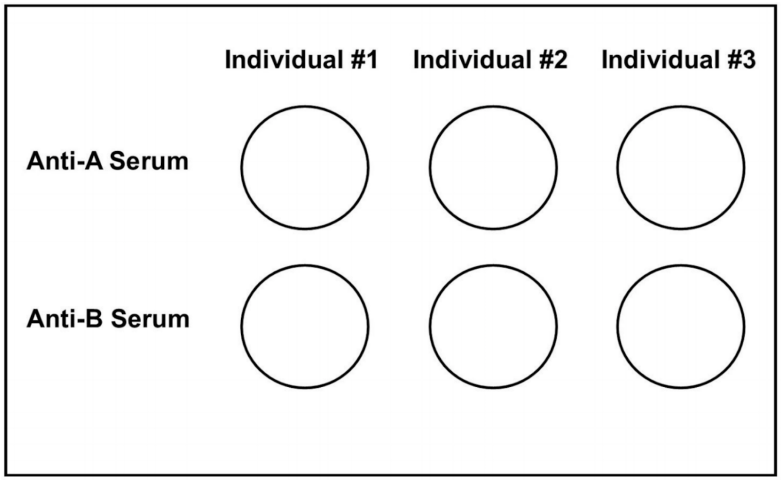
1. Observe each sample for coagulation. Based on what you see…
   a. What blood type does Individual #1 have? What is/are the possible genotype(s) for Individual #1?
   b. What blood type does Individual #2 have? What is/are the possible genotype(s) for Individual #2?
   c. What blood type does Individual #3 have? What is/are the possible genotype(s) for Individual #3?
2. Suppose that the three samples are from two parents and their child.
   a. Which individuals are the parents? Which individual is the child? How do you know?
   b. What genotype must each individual have for this scenario to be possible?

c. Draw a Punnett square using the parents' genotypes. Circle the genotype that belongs to the child that you have blood typed.
d. What is the percent chance that these two parents would have a child with this blood type?

3. There is one blood type not represented in these samples.
   a. What blood type is it?
   b. What would you predict would happen if you added Anti-A serum to this type of blood?
   c. What would you predict would happen if you added Anti-B serum to this type of blood?
   d. Why is the genotype that codes for this blood type considered "codominant"?

4. Is ABO considered a "Mendelian Trait"?
   a. What is "Mendelian genetics"? How would you identify a trait that follows a pattern of Mendelian genetics? Review the section "Mendelian Genetics" in Chapter 3 to help you.
   b. How does the ABO blood type system follow the rules of Mendelian Inheritance?
   c. In what ways is the ABO blood type system more complex than the pea plant traits that Mendel observed?

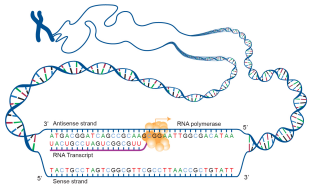
Blood Typing Test Plate



3.2: Protein Synthesis- One Act Play

Protein Synthesis: A One Act Play

Format: In-person



RNA polymerase carrying out transcription.

Author: Melissa Artstein-McNassar

Time needed: 45 minutes

Learning Objectives

- Demonstrate the processes of transcription and translation
- Identify the roles of the molecules involved in protein synthesis

Supplies Needed

- Printed badges identifying each actor (included):
  - DNA (A, T, C, G)
  - Ribosomes
  - mRNA
  - tRNA
  - RNA polymerase
  - Choice of amino acids (1-4)
- Chalk, masking tape, or small sports cones to map out the stage for the play
- Tape for student badges
- Amino acid chart
- Blank cards (badges) and a sharpie

Readings

-

Introduction

In this activity, students put on a play to perform what is happening inside their bodies. Students are given roles to act out the process of protein synthesis (specifically, transcription and translation). Students wear badges to distinguish their role from the roles of their peers. The goal of this play is to create a fictional protein. The instructor serves as play director and narrator.

Minimum required number of students: 11

Preferred number of students: 20 - 25

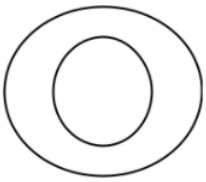
The Stage

Establish a cell that students can walk into. It is important to represent the boundaries of cell structure (nucleus and cell membrane) on the stage. Find a suitable space for the entire class to fit comfortably.

Outside: If conditions are favorable, this activity can be completed outdoors. Find a concrete or blacktop surface and use chalk to draw a rather large cell that includes two concentric circles that represent the boundaries of the nucleus and cell membrane. I recommend drawing the nucleus approximately six feet in diameter to accommodate students with an additional two or three feet around it to enclose the cell for students to fit within the cytoplasm.

Inside: Small soccer cones or tape on the floor can be used indoors to represent the boundaries of the cell (as indicated above). Furniture, such as chairs, or stools, can be used as well.

Boundaries should look like this:



Procedure: Setting Up

1. **Assign Roles.** Prior to showtime, assign student roles. List the various roles on the board and ask students to volunteer for each role. A minimum of eleven students are needed to successfully produce one amino acid for protein building, with roles assigned to students as follows:

Minimum Role to Student Ratio

Role	Minimum Students Required
DNA to make one codon	6
mRNA	1
tRNA	1
Ribosome	1
Amino acid	1
RNA polymerase	1

For larger class sizes (24 or more students), I recommend the following student assignments. Students can take turns being the "active" actor (for instance, the ribosome stringing together the two amino acids or RNA polymerase transcribing DNA).

Role to Student Ratio for Larger Classes

Role	Minimum Students Required
DNA to make two codons	12
mRNA	2
tRNA	2
Ribosome	2
Amino acid	2 (or more)
RNA polymerase	2

2. Prepare students. Students should be familiar with protein synthesis prior to the activity. See "For Further Exploration" (below) for a list of sources to introduce protein synthesis. You may wish to give students a bit of time to research their roles in or before class.

In addition, before showtime, students should know:

a. Where they need to start out on stage (for example, in the cell nucleus or in the cytoplasm).
b. Which other actors they will interact with during the play (for example, tRNA will need to find an amino acid and bring it to a ribosome).

Special note on DNA and amino acid roles: These two roles are linked. The DNA actors must arrange themselves so that they can be transcribed into a specific codon (amino acid). Students can take the lead on this and decide on one or two amino acid products. They will then need to arrange themselves in the correct order so that when RNA polymerase transcribes one half, it will

correspond to the appropriate amino acid. Students who are the amino acids need to have the appropriate signage so that they can be found in the cytoplasm when tRNA looks for them.

3. **Set the stage.** Identify the boundaries of the nucleus and cell. Refer to recommendations in the section labeled "The Stage" above.

Once students are comfortable with their roles, have them either hold their pieces of paper that indicate their roles visibly, or tape them onto their chests like a badge. RNA polymerase should have a blank badge and pen to record their transcription of DNA. RNA polymerase can record one codon on each blank badge. Ribosomes should have a codon to amino acid chart to consult to assist them in translating the mRNA message.

Lead the actors to the stage (the cell). All students initially stand outside the cell. First, point to the stage and explain the basic structure of the cell (e.g., nucleus, cytoplasm). Then, call students to take their places by introducing each role:

1. Narrator: "DNA will take their place in the nucleus and arrange themselves in a distinct way that will transcribe and translate to two (or one) amino acids"
   a. Students who play the DNA nucleotides (A, T, C, or G) line up in pair bonds, shoulder to shoulder, in a ladder-like formation in the nucleus.
2. Narrator: "RNA polymerase and mRNA will take their place along the edge of the nucleus."
   a. Students who are RNA polymerase and mRNA enter the nucleus. Keep in mind, students may not be able to fit in the nucleus.
3. Narrator: "Ribosomes will take their place in the cytoplasm."
   a. Students who are ribosomes will enter the cytoplasm area.
4. Narrator: "tRNA will take their place in the cytoplasm."
   a. Students who are tRNAa will enter the cytoplasm area.

Do this until all actors are on the appropriate areas of the stage.

Showtime: The Play

Once students are staged on the cell, the play will begin. Here is the basic narration of each step:

1. RNA polymerase breaks the bonds between bases throughout the DNA molecule.

2. RNA polymerase copies the DNA message and attaches it to mRNA.

3. mRNA leaves the nucleus and a ribosome approaches and attaches to the mRNA.

4. The ribosome read the mRNA code and give instructions to tRNA.

5a. tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome.

5b. If two amino acids are being called: The ribosome reads another mRNA codon and gives instructions to tRNA.

6. Ribosomes string the amino acids together to build a protein.

As the narrator is calling out the process, the students move and act accordingly. Here is an example of both the narration and student actions (movements):

1. **Narrator**: "RNA polymerase break the bonds between bases throughout the DNA molecule."

   - **Action**: RNA polymerase actor(s) begin to walk through the two rows of DNA base pairs, breaking the bond.

2. **Narrator:** "As the bonds break, RNA polymerase copies the DNA message to create mRNA"

   - **Action**: RNA polymerase actors begin at the beginning of the DNA message and, with pen and paper in hand, transcribe one side of the DNA. RNA polymerase then attach the message to mRNA.
   - *Note: If there are more than one RNA polymerase actors, they can check their work with one another to make sure the message is correct.*

3. **Narrator:** "mRNA leaves the nucleus and attaches to a ribosome."

- **Action**: mRNA actor leaves the nucleus area and arrives in the cytoplasm, seeks out a ribosome, and gives the message they have just transcribed to the ribosome.

4. **Narrator:** "The ribosome reads the mRNA code and gives instructions to tRNA."

   - **Action:** ribosome actor translates the mRNA code and yells out the appropriate amino acid that is needed.

5. **Narrator:** "tRNA takes the amino acid from the cytoplasm and shuffles it to the ribosome."

   - **Action**: tRNA actor hears the ribosome's call for an amino acid and searches the cytoplasm for the identified amino acid. tRNA actor takes the amino acid actor to the ribosome who yelled for the amino acid.
   - *Note: If two amino acids are being called, the ribosome may read both amino acids at one time and two tRNA actors may assist with finding and taking them to the ribosome.*

6. **Narrator:** "Ribosomes string the amino acids together to build a protein."

   - **Action:** The ribosome actor places the two amino acid actors side by side representing a protein.

Consider repeating the play a few times. The first time is slow, and then the second and third times are faster.

A note on "mistakes":
The first time through it will go a bit slower. The narrator may need to provide direction as to where the actors go, or to make sure each actor's signage is visible to others.

A common mistake that occurs is the mRNA polymerase does not transcribe the DNA correctly and/or the ribosome cannot translate the amino acid correctly. These are great examples of possible hiccups in the protein synthesis process that may account for a mutation. What an excellent teaching moment!

Review Questions

1. Protein synthesis is a 2 step process that includes transcription and translation. Where does each step take place within the cell?
2. Protein synthesis relies on many molecules and organelles in the cell. Identify the molecules and organelles found in each step. What part of this process seems the most vulnerable to mutation?

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt 3 Easy to adapt

For Further Exploration

Stated Clearly. What is DNA and How Does it Work? https://www.youtube.com/watch?v=zwibgNGe4aY

Amoeba Sisters. Protein Synthesis (Updated). https://www.youtube.com/watch?v=oefAI2x2CQM

References

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Explorations, Figure 3.22. Transcription by NIH National Human Genome Research Institute is in the public domain.

mRNA Codon chart by Becky Boone is used under a CC BY-SA 2.0 license.

Badges

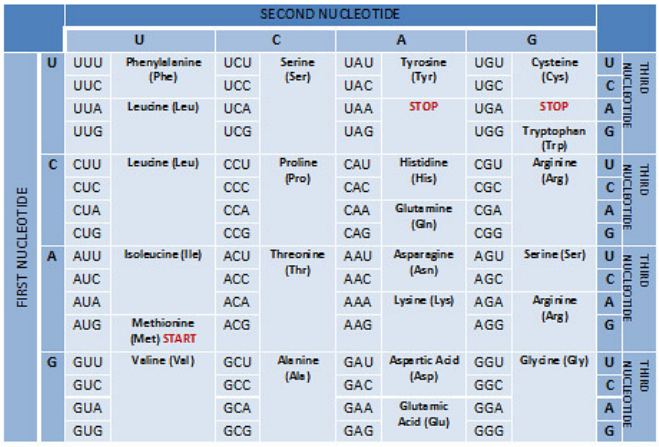
Print out the following roles and give them to students who will fill the roles. You may need to copy and paste several of the roles if you have multiple actors. Badges can be taped to actor's shirts.

A
T
C

G
Ribosome
mRNA
tRNA
RNA Polymerase
Methionine
Lysine
Proline
Leucine

Key

While there are many ways you can run your play to produce any of the 20 amino acids, below are four possibilities that correspond with the provided labels.



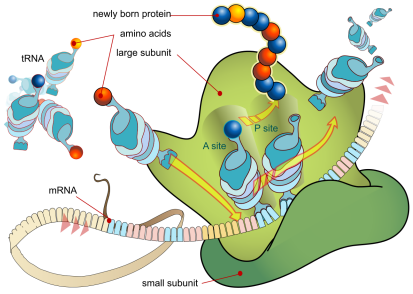
mRNA Codon Chart

Amino Acid	DNA	mRNA
Methionine	TAC	AUG
Lysine	TTT	AAA
Proline	GGA	CCU
Leucine	GAA	CUU

3.3: Protein Synthesis Pizza

Protein Synthesis Pizza

Format: In-person or online



A ribosome involved in translation - the last major step of protein synthesis.

Author: Jess Whalen

Source: Modified from Taco Protein Synthesis Activity, Susquehanna Township School District.

Time needed: 30-45 minutes

Learning Objectives

- Explain the roles of DNA, mRNA codons, ribosomes, and amino acids in protein synthesis
- Summarize protein synthesis: key steps and locations in a cell
- Practice transcription and translation

Supplies Needed

- Protein Synthesis Pizza Worksheet (included)
-
- Pizza Ingredients List (included)
- Optional Worksheets: Build Your Own Protein Pizza and Extra Practice: Go From RNA to DNA (included)
- DNA Sequences (included) printed and cut into strips

Readings

-

Introduction

In this activity, students work through the steps of transcription (DNA to RNA) and translation (RNA to amino acid chain) in protein synthesis. Instead of creating proteins, the final product is a pizza recipe with specific toppings. Just as a pizza is made up of many specific ingredients, so too is a protein made up of specific amino acids.

Steps

- Students should be divided into small groups of two or three.
- Each student begins with a copy of the Protein Synthesis Pizza Worksheet, the Amino Acids Reference Sheet or *Explorations* Figure 3.25 , and the Pizza Ingredients List. If you want to expand the activity you can also provide students copies of the Build Your Own Protein Pizza Worksheet.
- Instructors should pass out one DNA sequence to each group (provided on a paper strip).
- Students will work through the questions and record their answers on the Protein Synthesis Pizza Worksheet.

Review Questions

1. In what ways are proteins similar to pizza? How is relating proteins to pizza useful?
2. In our pizza metaphor, what are the amino acids?
3. What happened when your pizza had a few ingredients that were unexpected? What is the equivalent scenario when it comes to proteins? That is, which ingredients make up a protein, and what happens if a few ingredients are changed?

4. How do the exercises in this activity relate to natural selection?

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Instructors could provide students their own pizza recipe and the worksheet to do this activity individually, or instructors could distribute an electronic version of the worksheet and recipe (e.g. in Google Docs) and ask students to complete the activity in small groups online.

Tips and Suggestions

It can help to explain to students that their Amino Acids Reference sheet will show them how to transcribe the nucleotide bases from DNA to mRNA, and they may rely on this sheet to find the complementary nucleotide bases. Students usually use the chart for a few questions before they realize that they can actually transcribe the nucleotide bases faster by themselves. That means they are learning how to transcribe the bases from DNA to RNA!

A table like the one below may be helpful for students as they learn to transcribe DNA triplets into mRNA codons. The row in the middle is a 'help' row where students can insert a 'T' wherever there is an A in the DNA, or (if working backwards) where there is a 'U' in the RNA codon. The other nucleotides follow DNA rules of complementarity (A-T and C-G). This table structure matches the optional worksheet Extra Practice: Go from RNA to DNA (included)

DNA	AAA	TAC	GAC	GAA	AAT	ATT	GTT	ACA	ATT
help	TTT	_T_	_T_	_TT	TT_	T_ _	_ _ _	T_ T	T _ _
RNA	UUU	AUG	CUG	CUU	UUA	UAA	CAA	UGU	UAA

For Further Exploration

Leddin, Emmtt. Amino Acids and DNA and RNA Bases. https://emleddin.github.io/comp-chem-website/AMBERguide-AAs-DNA-RNA.html. CC BY-SA 4.0

Serendip Studios. Introduction to the Functions of Proteins and DNA. https://serendipstudio.org/exchange/bioactivities/proteins. CC BY-NC 4.0

Serendip Studios. How Genes Can Cause Disease - Introduction to Transcription and Translation. https://serendipstudio.org/exchange/waldron/gene. CC BY-NC 4.0

References

Mann, Hayley, Xazmin Lowman, and Malaina Gaddis. 2019. "Chapter 3: Molecular Biology and Genetics." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Ribosome mRNA Translation by LadyofHats has been designated to the Public Domain.

Protein Synthesis Pizza Worksheet

Background

Proteins are complex chemicals made up of different amino acids, of which there are a total of 20 types. Different combinations of amino acids produce different proteins. The process of making a protein is called protein synthesis, and involves two major steps: (1) transcription and (2) translation.

In transcription, a DNA strand in the nucleus forms the template for the creation of single-stranded messenger RNA (mRNA). Transcription occurs when an enzyme called polymerase strings together free-floating RNA nucleotide bases that are complementary to the exposed strand of DNA.

For translation, the mRNA strand leaves the nucleus for the cytoplasm. There, a ribosome translates the mRNA strand. Ribosomes read three nucleotides of the mRNA at a time (called a codon) and, with the help of single-stranded transfer RNA (tRNA), matches

the codon to the corresponding amino acid. This amino acid is added to the growing protein chain. When a 'stop' codon is read, the protein is complete. As the amino acid chain exits the ribosome, it folds into its unique shape, and can go to work in the body.

Part 1: From DNA to Amino Acids

This activity breaks down protein synthesis using the metaphor of PIZZA!

Warning: this activity may make you hungry!

Use your Amino Acids Reference Sheet to complete the following table. Fill in the blank spaces of each row with either the missing DNA triplet, the mRNA codon, or the Amino Acid. While there are actually multiple codons that code for any one amino acid, for this activity there only needs to be one DNA triplet and one corresponding mRNA codon recorded for each amino acid.

Remember: RNA uses uracil (U) instead of thymine (T)!

DNA	mRNA codon	Amino Acid
TTG	AAC	Asparagine
GGG		Proline
	UAU	Tyrosine
	CAC	Histidine
CGT	GCA	
AAA		
TTT	AAA	
CAA		

As you fill in the chart, you will learn how to transcribe the nucleotide bases of DNA (the As, Ts, Gs, and Cs) into mRNA using the "language" of RNA (which replaces any 'T' with a 'U'). As you continue to fill in the chart you may find that you can transcribe the triplets by yourself, using your knowledge of base pairings, without using the amino acids chart at all!

Part 2: Decoding a Protein Pizza

Your instructor will give you a DNA "pizza recipe" in DNA base triplets. Use your knowledge of transcription and translation to figure out what kind of pizza you have!

1. Write down the DNA pizza recipe in the DNA section of the chart, three letters at a time, going vertically down the chart in the far left column.
2. Transcribe each DNA triplet in the pizza recipe into a mRNA codon.
3. Once each triplet has been transcribed into mRNA, you can begin to translate the mRNA code to construct your pizza. Use the Pizza Ingredients List to decode what ingredients are in your pizza. The ingredients in the chart are in mRNA, so refer to your mRNA codons in the second column.
4. Use your Amino Acids Reference Sheet to figure out which amino acid corresponds to each mRNA codon. In this case you are doing the work of the ribosome: matching the mRNA codon to the specific amino acid that is needed for the growing protein chain. Just like all of the ingredients together make a tasty pizza, so too does each amino acid play an important role in making up a larger protein!

DNA **Pizza Recipe Code** **Write the recipe in this column, 3 nucleotides at a time.**	**mRNA** **Codon** **Transcribe the DNA code into the corresponding mRNA codon**	**Pizza ingredient** **Record the corresponding pizza ingredient, according to the ingredients chart (Use the mRNA codon to look it up.)**	**Amino Acid** **Record the corresponding amino acid (for a protein) using your amino acid chart!**
Example: *AAA*	*Example:* *UUU*	*Example:* *Stuffed crust*	*Example:* *Phenylalanine*

Part 3: Reflection

Did your pizza have any ingredients that you would not usually find on a pizza? Just like one ingredient can make a pizza unique, so too can one new or different amino acid create a protein that is different from the protein that was supposed to be synthesized. DNA mutations that change, move, or delete a letter in the original DNA triplet can, through protein synthesis, result in the creation of different and new proteins in the body.

A protein that differs from the original protein that was supposed to be produced can sometimes be a good thing for an organism. If the protein results in a new functioning that gives the

organism an advantage in its environment then the “incorrect” protein would be beneficial, helping the organism achieve reproductive success. That protein could be selected for through the process of natural selection. In that case, the “incorrect” protein would increase in frequency in the population, and become the more common protein over time (and no longer be considered “incorrect”).

Amino Acids Reference Sheet

The 20 Amino Acids in Human Proteins and How They Are Coded For

Cells in the human body use information in the genetic code to directly encode 20 amino acids. The table below displays how this is done. First, a DNA base triplet is copied to create mRNA in the language of RNA. The mRNA then travels to the cytoplasm, where the ribosome reads each mRNA codon to assemble the corresponding amino acids into a growing protein chain. The “stop” codon is the last triplet in the process. It tells the ribosome that the process of making that specific protein is complete.

This table lists DNA base triplets and their corresponding mRNA codons that the ribosome reads to attach each specific amino acid. Some amino acids can be made more than one way.

Amino acids that can be made one way:

Amino Acid	DNA base triplet	mRNA codon
Methionine	TAC	AUG
Tryptophan	ACC	UGG

Amino acids that can be made two ways:

Amino Acid	DNA base triplet	mRNA codon
Asparagine	TTA or TTG	AAU; AAC
Aspartate	CTA or CTG	GAU; GAC
Cysteine	ACA or ACG	UGU; UGC
Glutamate	CTT or CTC	GAA; GAG
Glutamine	GTT or GTC	CAA; CAG
Histidine	GTA or GTG	CAU; CAC
Lysine	TTT or TTC	AAA; AAG

Phenylalanine	AAA or AAG	UUU; UUC
Tyrosine	ATA or ATG	UAU; UAC

Amino acids that can be made three ways:

Amino Acid	DNA base triplet	mRNA codon
STOP codon	AAT or ATC or ACT	UAA; UAG; UGA
Isoleucine	TAA or TAG or TAT	AUU; AUC; AUA

Amino acids that can be made four ways:

Amino Acid	DNA base triplet	mRNA codon
Alanine	CGA or CGG or CGT or CGC	GCU; GCC; GCA; GCG
Glycine	CCA or CCG or CCT or CCC	GGU; GGC; GGA; GGG
Proline	GGA or GGG or GGT or GGC	CCU; CCC; CCA; CCG
Threonine	TGA or TGG or TGT or TGC	ACU; ACC; ACA; ACG
Valine	CAA or CAG or CAT or CAC	GUU; GUC; GUA; GUG

Amino acids that can be made six ways:

Amino Acid	DNA base triplet	mRNA codon
Arginine	GCA or GCG or GCT or GCC or TCT or TCC	CGU; CGC; CGA; CGG; AGA; AGG
Leucine	AAT or AAC or GAA or GAG or GAT or GAC	UUA; UUG; CUU; CUC; CUA; CUG
Serine	AGA or AGG or AGT or AGC or TCA or TCG	UCU; UCC; UCA; UCG; AGU; AGC

Pizza Ingredients

Important: All ingredients are based on the mRNA code!

Basics: GCA - Thick crust GUA - Thin crust UUU - Stuffed crust	**Acidics:** CUA - Marinara sauce CUG - Barbecue sauce CUU - White sauce UUA - Garlic sauce
Aromatics: AAA - Pepperoni AAG - Sausage ACC - Chicken AUA - Bacon AUG - Pineapple	**Hydroxylics:** AGA - Mozzarella cheese UGU - Extra cheese (mozzarella)
Aliphatics: AAU - Red onion CAA - Black olives CCA - Animal crackers CGA - Spinach GAU - Mushrooms GGA - Lettuce GUU - Artichoke hearts	**Stop codons:** UAA - Stop codon UAG - Stop codon UGA - Stop codon

*Remember: All ingredients are based on the mRNA code!

Build Your Own Protein Pizza

Choose from the ingredients list to make your own pizza! Remember: because the ingredients are in mRNA, you have to fill in the chart working right to left from the Pizza Ingredient. Amino acids can be looked up at the end.

DNA **Pizza Recipe Codons (write the recipe in this column, 3 letters at a time)**	**mRNA** **Codon** **(Once the DNA triplet is transcribed into mRNA, you can find the pizza ingredient)**	**Pizza Ingredient** **What pizza ingredient is this, according to the ingredients chart? (Remember: the ingredients in the chart are in mRNA!)**	**Amino Acid** **Once you have completed the activity, look up what amino acid this ingredient corresponds to in real life!**
Example: *TCT*	*Example:* *AGA*	*Example:* *Mozzarella cheese*	*Example:* *Arginine*

Extra Practice: Go From RNA to DNA

Work backwards from the RNA strand to find the original DNA base triplet! Remember: RNA uses U (not T). So every time you see ‘U’ in the RNA strand, treat it just like ‘T’ to find the complementary nucleotide base!

DNA	___	___	___	___	___	___	___	___	___
RNA	UUU	AUG	CUG	CUU	UUA	GAU	CAA	UGU	UAA

DNA	___	___	___	___	___	___	___	___	___
RNA	AAA	GUA	AUG	CUA	UUA	GUU	CGA	AAU	UAG

DNA	___	___	___	___	___	___	___	___	___
RNA	GCA	AAG	UUA	GUU	UGU	CGA	CCA	AGA	UGA

DNA	___	___	___	___	___	___	___	___	___
RNA	GCA	AUG	CGA	AGA	GAU	CUU	UUA	CUA	UAA

DNA	___	___	___	___	___	___	___	___	___
RNA	ACC	CCA	AAU	GUA	GGA	CUU	UUA	GUU	UAG

DNA	___	___	___	___	___	___	___	___	___
RNA	AUA	AGA	UGU	ACC	AAU	GAU	CUU	UUU	UGA

DNA Sequences to Provide Students

DNA	AAA	TAC	GAC	GAA	AAT	CTA	GTT	ACA	ATT

DNA	TTT	CAT	TAC	GAT	AAT	CAA	GCT	TTA	ATC

DNA	CGT	TTC	AAT	CAA	ACA	GCT	GGT	TCT	ACT

DNA	CGT	TAC	GCT	TCT	CTA	GAA	AAT	GAT	ATT

DNA	TGG	GGT	TTA	CAT	CCT	GAA	AAT	CAA	ATC

DNA	TAT	TCT	ACA	TGG	TTA	CTA	GAA	AAA	ACT

DNA	TTT	AAA	TTA	GTT	ACA	TCT	CAA	GAT	ATT

DNA	TAC	CAT	TCT	ACA	AAT	CAA	GCT	CTA	ATC

DNA	CGT	GAC	TTC	AAT	CTA	CCT	TTA	TCT	ACT

Answer Key (RNA & Protein)

UUU AUG CUG CUU UUA GAU CAA UGU UAA

Stuffed crust, pineapple, barbecue sauce, white sauce, garlic sauce, mushrooms, black olives, extra cheese, stop

AAA GUA AUG CUA UUA GUU CGA AAU UAG

Pepperoni, thin crust, pineapple, marinara sauce, garlic sauce, artichoke hearts, spinach, red onion, stop

GCA AAG UUA GUU UGU CGA CCA AGA UGA

Thick crust, sausage, garlic sauce, artichoke hearts, extra cheese, spinach, animal crackers, mozzarella cheese, stop

GCA AUG CGA AGA GAU CUU UUA CUA UAA

Thick crust, pineapple, spinach, mozzarella cheese, mushrooms, white sauce, garlic sauce, marinara sauce, stop

ACC CCA AAU GUA GGA CUU UUA GUU UAG

Thin crust, animal crackers, red onion, mushrooms, lettuce, white sauce, garlic sauce, artichoke hearts, stop

AUA AGA UGU ACC AAU GAU CUU UUU UGA

Bacon, mozzarella cheese, extra cheese, chicken, red onion, mushrooms, white sauce, stuffed crust, stop

AAA UUU AAU CAA UGU AGA GUU CUA UAA

Pepperoni, stuffed crust, red onion, black olives, extra cheese, mozzarella cheese, artichoke hearts, marinara sauce, stop

AUG GUA AGA UGU UUA GUU CGA GAU UAG

Pineapple, thin crust, mozzarella cheese, extra cheese, garlic sauce, artichoke hearts, spinach, mushrooms, stop

GCA CUG AAG UUA GAU GGA AAU AGA UGA

Thick crust, barbecue sauce, sausage, garlic sauce, mushrooms, lettuce, red onion, mozzarella cheese, stop

CHAPTER OVERVIEW

4: Forces of Evolution

Learning Objectives

- Perform calculations to determine change in allele frequencies within a population
- Document how a selective pressure can change allele frequencies and can cause evolution to occur in the ant population.
- Write and test a hypothesis

Thumbnail: An insectivorous primate (marmoset) eating a grasshopper.

4.1: Natural Selection Lab

Natural Selection

Format: In-person or online

Authors: Julie Wieczkowski, Susan Maguire, Melanie M. Mayberry, and Lisa Marie Anselmi

Time needed: 30-40 minutes

Supplies Needed

- Calculator

Readings

- Alveshere, Andrea J. 2019. Chapter 4: Forces of Evolution. *Explorations.*
-
- Coty-Barker, Valencia. How to Form a Hypothesis.

Introduction

This lab allows students to see the impact of a selective agent, an insectivorous primate, on a population of ants. There are green and brown ants present in the population. In the rainy season, the primate eats the ants from green leaves. In the dry season, the primate eats the ants from brown branches. Calculating allele frequencies for several generations of ants in both seasons, the students will see how allele frequencies change in response to the selective pressure.

Steps

- Review dependent and independent variables, as well as key content from chapter four including natural selection, selective pressures, allele frequencies, and microevolution.
- Distribute student handouts. Students can work through the handout independently or in small groups.

Conclusion

There are things in the environment (selective pressures or agents) that select for or against certain phenotypes. These selective agents can cause allele frequencies to change, thereby causing evolution (microevolution in this population) to occur.

If the environment changes, the phenotype that is selected for may now be selected against. This illustrates that evolution does not proceed in only a one-way direction. This example also illustrates an important point about natural selection: there must be individual-level variation present in the population in order for natural selection to work.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Students can work through this activity individually as an assignment or in small groups (synchronously online). Students will need a clear introduction to the concepts ahead of time, and time to ask questions if students have them.

References

Alveshere, Andrea J. 2019. “Chapter 4: Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Helmenstine, Anne Marie. 2019. What are Independent and Dependent Variables? *Thought Co.* https://www.thoughtco.com/independen...xamples-606828

Coty-Barker, Valencia. July 10, 2013. “How to Form a Hypothesis.” YouTube video. https://www.youtube.com/watch?v=bp2f...ature=youtu.be

Image Attributions

Marmoset eating a grasshopper by Tambako the Jaguar is designated under a CC BY-ND 2.0 license.

Natural Selection: Worksheet

Imagine your anthropology professor studies a primate that eats insects. The primate's favorite food is a type of ant. She asks if you are interested in helping her analyze the data. You, of course, say yes!

Your professor tells you more about the ants, the primates, and the habitat. Ant color is determined by one gene. There are two alleles for this color gene: the brown allele and the green allele. The primates eat the ants year-round, but your professor knows that the way they eat the ants differs between the rainy season and the dry season. During the rainy season, when there are green leaves on the trees, the primates eat the ants off the green leaves. During the dry season, when the trees lose their leaves, the primates eat the ants off the brown tree branches.

Your professor has collected data to investigate if the primate acts as a selective pressure on the ant population, possibly changing the allele frequencies over time.

Step One: Hypothesis

You need to start with a hypothesis. The following questions will help you to frame your hypothesis.

1. How do the ants vary?
2. What is the selective pressure?
3. What is the dependent variable?
4. What is the independent variable?
5. Now, write a hypothesis for the following question: During the rainy season, which allele frequency (brown or green) will increase over time?

Step Two: The Rainy Season Data

Your professor is happy with the hypothesis that you have written. She gives you the data that she collected on the ant population. Because of the fast rate of reproduction among ants, she was able to collect a number of ants of each color over four generations. The data are in the table below.

Table 1: Number of ants collected during the rainy season

Generation of ants	Brown ants	Green ants	Total ants
Generation 1	100	100	200
Generation 2	90	120	210
Generation 3	75	150	225
Generation 4	65	170	235

Calculate the frequency of the brown allele and of the green allele in each of the generations. We assume that each ant is a homozygote. Round to the nearest thousandths.

To calculate allele frequencies within each generation:

1. Calculate the number of brown alleles by multiplying the number of brown ants (from Table 1) by 2. Calculate the number of green alleles by multiplying the number of green ants (from Table 1) by 2. Write in Table 2.
2. Calculate the total number of alleles by adding the number of brown alleles and the number of green alleles. Write in Table 2.
3. Calculate the brown allele frequency by dividing the number of brown alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 2.
4. Calculate the green allele frequency by dividing the number of green alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 2.
5. Check your math by calculating the total allele frequency. Write in Table 2.

Table 2: Allele frequencies in the rainy season

	Generation 1		Generation 2		Generation 3		Generation 4	
	brown	green	brown	green	brown	green	brown	green
Number of alleles								

Total # alleles in generation (brown + green)								
Allele frequency								
Total allele frequency in generation (brown + green)								

Answer the following questions based on the above (rainy season) data.

1. What was the general trend (comparing Generation 1 to Generation 4) of the brown allele frequency over the four generations? Did the brown allele frequency increase or decrease? Write the actual numbers for each generation here in support of your answer.
2. What was the general trend (comparing Generation 1 to Generation 4) in the green allele frequency over the four generations? Did the green allele frequency increase or decrease? Write the actual numbers for each generation here in support of your answer.
3. Was your hypothesis in Question 1 supported? Explain why or why not.

Step Three: The Dry Season Data

During the dry season, the trees lose their leaves. The primates now eat the ants off of the brown tree branches.

1. In this environment, which allele frequency (brown or green) do you hypothesize will increase over time?

Table 3: Number of ants collected during the dry season

Generation of ants	**Brown ants**	**Green ants**	**Total ants**
Generation 1	65	170	235
Generation 2	90	150	240
Generation 3	125	120	245
Generation 4	150	100	250

Calculate the frequency of the brown allele and of the green allele in each of the generations. We assume that each ant is a homozygote. Round to the nearest thousandths.

To calculate allele frequencies: Within each generation,

1. Calculate the number of brown alleles by multiplying the number of brown ants (from Table 3) by 2. Calculate the number of green alleles by multiplying the number of green ants (from Table 3) by 2. Write in Table 4.
2. Calculate the total number of alleles by adding the number of brown alleles and the number of green alleles. Write in Table 4.
3. Calculate the brown allele frequency by dividing the number of brown alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 4.
4. Calculate the green allele frequency by dividing the number of green alleles by the total number of alleles. Round to the nearest thousandths. Write in Table 4.
5. Check your math by calculating the total allele frequency. Write in Table 4.

Table 4: Allele frequencies in the dry season

	Generation 1		Generation 2		Generation 3		Generation 4	
	brown	green	brown	green	brown	green	brown	green
Number of alleles								
Total # alleles in generation (brown + green)								
Allele frequency								

Total allele frequency in generation (brown + green)				

Answer the following questions based on the above (dry season) data.

1. What was the general trend (comparing Generation 1 to Generation 4) in allele frequency that you observed for the brown allele over the four generations? Did the brown allele increase or decrease in allele frequency? Write the actual numbers for each generation here in support of your answer.
2. What was the general trend (comparing Generation 1 to Generation 4) in allele frequency you observed for the green allele over the four generations? Did the green allele increase or decrease in allele frequency? Write the actual numbers for each generation here in support of your answer.
3. Was your hypothesis at the beginning of Step Three supported? Explain why or why not.

Step Four: Wrap Up

The following questions refer to the whole lab.

1. How did the ants in this population vary? In other words, what is the main difference between them?
2. Why is variation necessary for natural selection to work?
3. Explain selective pressure. What was the selective pressure in this simulation?
4. What is the definition of allele frequency? How are allele frequencies related to the idea of evolution?
5. Because some individuals in a population are more fit than others, the ultimate result of natural selection is a population that is better adapted to its environment. a. What trait was adaptive in the rainy season?
   b. What trait was adaptive in the dry season?
   c. Are your answers for a) and b) the same or different? If different, what changed between the two seasons to cause this difference?
6. Define microevolution. Define macroevolution. Which did you observe in this ant population? Explain why?

4.2: Bingo Chip Evolution

Bingo Chip Evolution

Format: In-person or online

Bingo chips can be used to simulate a population of simple organisms reproducing and spreading in this evolution activity.

Author: Cara Ocobock

Source: Modified from Lee et al. 2017. Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change. *Evolution: Education and Outreach* which is under a CC BY 4.0 License.

Time needed: 60 - 90 minutes

Learning Objectives

- Calculate allele frequencies to document evolutionary change in a population
- Identify the evolutionary forces
- Model and describe the founder effect, gene flow, genetic drift, natural selection, and population bottleneck

Supplies Needed

- Bingo chips (or beads). Each set of chips for each group of students should include approximately 200 chips (50 chips of each color).
- Student worksheet (provide)

Readings

-

Introduction

This activity utilizes bingo chips to represent a population of organisms reproducing over several generations. Over time, the population of Bingo Chips expands to occupy both the mainland and island coastlines, as both regions experience various evolutionary forces. With each generation, student researchers follow the directions on their worksheet to modify their population as a result of these forces, and then record the new allele frequencies.

Steps

- Instructors will provide an overview of the Bingo Chip population, including how an organism can be haploid and reproduce via the budding process. Instructors should demonstrate how to calculate allele frequencies for the population of bingo chips.
- Students divide into small groups and are given a set of bingo chips and the student worksheet(s). At their table, students should map out the location of the island and mainland, where the bingo chips live. Students then place the first eight Bingo Chips (two bingo chips of each of the four colors) at the mainland location to begin the activity.
- Students will follow the instructions on the student worksheet, changing the Bingo Chip populations as directed.
- For each generation, students will record the number of alleles present on the tables in their worksheet. If there is sufficient time, students should be encouraged to convert these into allele frequencies. For example if 2 of 8 of the allele on the mainland are pink, the frequency of the pink allele is 2/8 = 0.25.
- For each generation students will also discuss answers to the questions on the worksheet.

Conclusion

After each group has worked through the six generations of activities, each group should identify and share with the rest of the class:

- The final allele frequencies for both their mainland and island populations.
- The force(s) they think had the largest effect towards changing the allele frequencies, and what those changes were. Students should refer back to their tables to support their statements.
- Which event(s)/evolutionary force(s) led to the loss of any alleles in either the mainland or island population. If genetic bottleneck or the founder effect are noted, instructors can help students identify that both are types of genetic drift.

Students should compare the populations of the various small groups to identify the differences between the groups, despite that all groups experienced similar types of events/evolutionary forces. This can be tied to the random nature of many evolutionary forces.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This activity can be completed online. While students could do it individually on their own, it would be best completed in small groups synchronously (e.g. via Zoom) utilizing breakout rooms. The provided Bingo Chips Evolution Slides can be copied and modified for online classes. Individuals or small groups of students can be given edit access to complete the activities in the slides themselves. Each individual or small group of students should be provided a copy of the first couple of slides. They can then copy and paste the slide of the generation they are working on and proceed to the next generation (the next step of the activity). Each generation should have its own slide. This version of the lab is nice, as a record of each generation is preserved on a slide and can be reviewed at the end of the activity. Also, instead of recording allele frequencies in the worksheet, students can record allele frequencies on the slides.

Tips and Suggestions

Other materials can be used for this activity such as beads or post-it notes, as long as there are sets with at least 4 different colors. At its peak there are a lot of “bingo chip” organisms, so it will be important that each student set has at least 50 objects of each color.

References

Alveshere, Andrea. 2019. “Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington,

VA: American Anthropological Association. http://explorations.americananthro.org/

Ocobock, Cara. Bingo Chip or Sticky Note Evolution. University of Notre Dame.

Teresa W. Lee, Kathleen E. Grogan and Justine S. Liepkalns. 2017. Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change. *Evolution: Education and Outreach* 10:11. Open Access; CC BY 4.0 License

Lee et al. 2017. Making evolution stick: using sticky notes to teach the mechanisms of evolutionary change. *Evolution: Education and Outreach* which is under a CC BY 4.0 License. This *Explorations* lab is modified from this source.

Image Attributions

Bingo Chips #3 by Scott Ableman at flickr is used under a CC BY-NC-ND 2.0 License.

Bingo Chip Evolution Worksheet

Introduction

Your team has discovered a new population of Bingo Chips that lives along the coast. This organism is haploid, meaning it only has one copy of each chromosome. It has one visible phenotype (color), which is determined by the Color Gene. Like budding yeast, Bingo Chips reproduce clonally via a budding process, resulting in two individuals who have the same genome and phenotype.

They are exceptionally long-lived, meaning that each Chip can reproduce for many generations. Everything these Chips need to survive is on the coast. They can see an island off in the distance, but cannot reach it.

Generation 1: Establish Your Own Population of Bingo Chips

There will be two Bingo Chips of each color. Bingo Chips are haploid, so each chip represents only one allele. The initial phenotype ratios are recorded for you already in the table below but you will need to record them yourself in future generations.

Generation 1	Green	Blue	Pink	Yellow
Mainland	*2 / 8 = 0.25*	*2 / 8 = 0.25*	*2 / 8 = 0.25*	*2 / 8 = 0.25*
Island	*0*	*0*	*0*	*0*

Discuss:

- Bingo Chips are haploid, so how many alleles does a single Bingo Chip have for the Color Gene?
- How many total alleles for the color gene exist in the population during generation 1?

Generation 2: The Founder Effect

A rare low tide has exposed a temporary sandbar. Some curious Bingo Chips take this opportunity to explore the nearby island, but they’re stuck there once the sandbar is covered.

Task:

- Move a few Bingo Chips of any color to the island (no more than three).
- After this tragic separation, each Chip will clonally reproduce one time. For each Bingo Chip on the island and the mainland, add another Bingo Chip of the same color to that same population.
- Record your new allele frequencies in the table below, considering the two populations separately.

Generation 2	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- After reproduction, how do the **mainland** phenotypic frequencies of Generation 2 compare to those on the **mainland** in Generation 1?
- After reproduction, how do the **island** phenotypic frequencies of Generation 2 compare to those on the **mainland** in Generation 1?

Generation 3: Gene Flow

Every so often the currents are favorable and allow some Bingo Chips to move from the island to the mainland or vice versa.

Task:

- One member of your group will choose up to five intrepid Bingo Chips to move from one population to the other. Some can move from the island to the mainland, while others can move from the mainland to the island.
- After the migration, each Bingo Chip reproduces clonally one time. For each Bingo Chip on the island and the mainland, add another Bingo Chip of the same color to that same population.
- Record your new allele frequencies in the table below.

Generation 3	Green	Blue	Pink	Yellow

Mainland				
Island				

Discuss:

- Does evolution occur if a Bingo Chip migrates from the island to the mainland, but then dies without reproducing? Why or why not?

Generation 4: Genetic Drift

You and your team have gone to get more supplies to continue your work at the field site, so several generations go by before you can make an observation of these populations.

Task:

- Choose another group member to act out the effects of genetic drift. They will close their eyes and point to the screen, open their eyes and remove the closest two Chips from the mainland population, and do it again to remove two Chips from the island population. These unfortunate Bingo Chips have perished before they are able to reproduce.
- All the remaining Bingo Chips will reproduce clonally one time.
- The same group member will close their eyes and now remove eight Chips from the mainland population and eight from the island population.
- All the remaining Bingo Chips will reproduce clonally once again.
- Record your new allele frequencies in the table below.

Generation 4	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- Which color, if any, has become more prevalent in the **mainland** population? Which color has become more rare?
- Which color, if any, has become more prevalent in the **island** population? Which has become more rare?
- Which population looks most different from your original population at Generation 1?

Generation 5: Natural Selection

A dreaded flying predator has entered the area and is eating many of the bingo chips!

Task:

- Choose a group member to act as a predator of the Bingo Chips. This group member will choose their two favorite colors of Chips to eat. This group member will "fly" between the island and the mainland, removing ten Bingo Chips of these two colors in total (decide how many to eat from each population).
- All the remaining (and relieved) Bingo Chips will reproduce clonally one time.
- Record your new allele frequencies in the table below.

Generation 5	Green	Blue	Pink	Yellow
Mainland				
Island				

Discuss:

- What characteristics of Bingo Chips or their environment might help one color of Bingo Chip survive better than another?
- Does evolution happen if a Bingo Chip is better at surviving, but would not reproduce?

Generation 6: Population Bottleneck

An event of mass destruction (hurricane? earthquake? zombies?) causes Bingo Chips to die in alarming numbers! Which ones die depends on the event but not on their phenotype (color). Will it be proximity to the ocean? Disease susceptibility? Completely at random?

- Decide as a group what the event of mass destruction will be.
- Choose a group member to become a force of nature. This person will remove all but ten Bingo Chips (split the survivors between the two populations).
- These (extremely shaken) Bingo Chips are grateful to have survived and begin to rebuild their lives. They reproduce clonally one more time.
- Record your final allele frequencies in the table below.

Generation 6	Green	Blue	Pink	Yellow
Mainland				
Island				

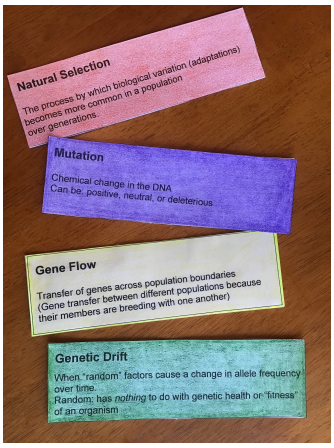
Discuss:

- Have any colors disappeared in either population? Will there be any Bingo Chips of this color in future generations?
- Now that you have completed your field season, describe what happened to each color of Bingo Chip over the generations you've observed. You will report this back to the entire class.

4.3: Evolutionary Detectives

Evolutionary Detectives

Format: In-person or online



Cards of various colors help students to identify which forces of evolution are occurring - and the instructor can quickly tell where clarification is needed.

Author: Jess Whalen

Time needed: 60-90 minutes

Learning Objectives

- Distinguish between the different forces of evolution
- Identify which force(s) of evolution are at work in a given scenario
- Observe how multiple forces of evolution may work together to cause change in a population

Supplies Needed

- Forces of evolution cards (included). Each force should be printed on paper of a different color.
- Student worksheet with case studies (included)

Readings

- Alveshere, Andrea J. 2019. Chapter 4: Forces of Evolution. *Explorations.*

Introduction

In this activity, students will be reading short case studies and identifying what forces of evolution are at work, and how those forces work together to cause change in a population. This activity also utilizes colored “forces of evolution” cards so that groups can visually report their answers at the end of the activity.

Steps

- Students should be divided into small groups (of two to three).
- Each group should be given one set of four evolutionary forces cards (each card is a different color) and copies of the student worksheet with case studies and questions.
- Students will work through the case studies, using the evolutionary forces cards to help them differentiate between the forces. They will develop narratives that identify and explain which forces are operating in each case study, and record their answers on the student worksheet.

Conclusion

Talk through the case studies as a class, one case study at a time. Allow students time to work through the case study as a group and decide what forces are operating.

After groups work through a case study the instructor can ask, “What forces are operating? Hold up your cards!”. At that point the cards typically create a sea of purple, orange, etc. The colors help the instructor identify who is having trouble, and class-wide discussion can help identify why.

A class-wide discussion that explains why specific forces are operating in this case study, and why other forces are not operating, will help clarify for students the differences between the different “forces”. For instance, students often have difficulty distinguishing between gene flow/admixture and genetic drift. Clarifying that the founder effect (a type of genetic drift) involves a situation where organisms migrate to a new place and find no other organisms of their own species in that new place that they can mate with, helps students to understand the difference between genetic drift and gene flow. The organisms that migrate to that new place have no choice but to mate only amongst each other. This is different from gene flow, where alleles are carried by new migrants into a population of already existing organisms of that same species, and interbreeding occurs.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

Students could be provided the worksheets to do this activity individually for submission, or given an electronic version of the colored forces of evolution cards and case studies (e.g. in Google Slides) and asked to complete the activity in small groups during a synchronous activity time.

Tips and Suggestions

I recommend making the gene flow and the genetic drift cards strikingly different colors as these two concepts are frequently confused by students.

Be sure to welcome all ideas and explain that this is a difficult activity, or else students will be shy about holding up the cards that correspond with their genuine thoughts about the case studies. What you do not want is for students to copy the majority decision because they are afraid to guess incorrectly! Normally, there are many “errors” in the forces that students identify. You want to encourage those “errors” and talk through why a case study involves some forces, but not other forces. Along the way you can clarify the differences between the “forces”. This should be very tricky for everyone involved - when a class does this perfectly, it signals to me that many are hiding that they are having trouble!

For Further Exploration

Andersen, Paul. Five Fingers of Evolution. TedEd Animation and Lesson. https://ed.ted.com/lessons/five-fingers-of-evolution

Andrews, Christine A. 2010. Natural Selection, Genetic Drift, and Gene Flow Do Not Act in Isolation in Natural Populations.*Nature Education Knowledge* 3(10):5 https://www.nature.com/scitable/knowledge/library/natural-selection-genetic-drift-and-gene-flow-15186648/

References

Alveshere, Andrea J. 2019. “Chapter 4: Forces of Evolution.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Evolutionary Detectives

Introduction

Evolutionary biologists reconstruct evolutionary processes like detectives. They compare the frequency of alleles in a population over time, and use their understanding of evolutionary forces to work out what’s happened to cause any shifts in allele frequencies. In this activity, you will do the same!

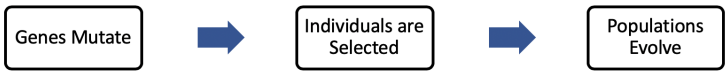
Change in a population over time is the result of any combination of the four “forces" of evolution. But which forces are occurring? We can figure this out by considering the order in which the “forces” typically occur, and work out a narrative - a story - by which this happens.

You can remember the forces of evolution as a sequence of stages:

Genes Mutate,

Individuals are Selected,

Populations Evolve.



Mutations are the only “force” of evolution that adds completely new variation to a population, so it comes first. The other “forces”- Natural Selection, Genetic Drift, and Gene Flow/Admixture - move this variation around in a population.

Instructions

For each of the following cases:

- Identify which forces of evolution are occurring,
- Identify if natural selection is present, and if so, how it is operating, and,
- Put this information into a coherent narrative (story) that explains how, exactly, evolution is taking place. For this step, you will need to identify the sequence by which the forces that you identified are actually occurring.

Quick Recap: Distinguishing Between the Forces

First, consider if the case study involves the introduction of new alleles - either through mutation, or through gene flow/admixture (the transfer of alleles between populations). New alleles means new traits, which can provide natural selection more variation to act upon.

If natural selection is occuring, then individuals with traits that are a better “fit” with the environment will be selected for, or favored. That means individuals with advantageous traits will have an easier time finding food, avoiding predators, surviving to reproductive age, and/or reproducing successfully and sending their traits (and the alleles that control those traits) into the next generation.

If genetic drift is occurring, we will see traits (and the alleles that control them) either increasing or decreasing in frequency, perhaps even being eliminated from a population, due to chance. This may correlate with events like natural disasters (floods, earthquakes, etc.), but also with events like overhunting by humans, or migration into a new area. With genetic drift there is no interaction between traits and the environment: it does not matter if the organism has traits that are a good “fit” with the environment. Those who survive and pass on their genes are the “lucky” ones, not the ones with the best traits.

Case #1: The Story of the Peppered Moth

In Great Britain, prior to the 1800s, most peppered moths had wings that were white with black specks. In 1848, a new ‘species’ was spotted: a completely black moth! By the 1950s, one hundred years later, more than 90% of moths were black.

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how

individuals are selected, and how alleles shift over time.

Case #2: Sickle-Cell Anemia

As many as 20-30% of people living in equatorial Africa have at least one allele on Chromosome 11 that codes for sickle-cell anemia (they have an, “S” rather than an, “A” allele). This is odd because usually, 80% of people who have two S alleles die before they can reproduce - so why is the allele still around?

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #3: Lactase Persistence

Being able to digest lactose after the age of four is **common / uncommon** (circle one) around the world. 77% of European Americans and 14% of African Americans have the LCT gene on Chromosome 2, which codes to produce the enzyme lactase, which allows people to digest lactose in adulthood.

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #4: Founding the Colony of Zygozia

Let’s pretend that there is a community called Zygozia. They say that they founded their small island colony in the South Pacific in 1959. When they arrived, there were no people living on the island, and so they became the only inhabitants. They came ‘from the west’, most likely Southeast Asia. The Zygozians of 2018 are unusual in that 80% of them have a rare genetic condition. Populations from Southeast Asia, whom the Zygozians descended from, only show this condition in 3% of their population. What happened?

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Is natural selection involved? If it is, then how, specifically is it operating?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the ‘forces’ of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #5: Native Americans and Type O Blood

Modern Native Americans have very high frequencies of Type O blood. In some places in North and South America, the frequency is as high as 100%. Anthropologists believe that early Native Americans arrived in North America by crossing over the Bering Land Bridge around 15,000 years ago, from East Asia. Modern East Asian populations, with whom modern Native Americans share ancestry, do not have high frequencies of Type O blood. Instead, they have some of the lowest frequencies of Type O blood in the world.

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Specifically, how is natural selection involved?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #6: Malaria in the Tropical Americas

Today, malaria appears throughout the tropical Americas. However, Native American populations only have "normal" hemoglobin (they are 100% homozygous for normal alleles and do not have any hemoglobin variations that protect them from malaria, as is seen in human populations in Africa, Asia and Europe). Why do Native Americans not exhibit any genetic diseases that make them better able to survive malaria?

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Specifically, how is natural selection involved?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

Case #7: Skin Color Around the World

Around the world, populations near to the equator and in areas of high altitude have darker skin (their skin produces more melanin). Populations at northern latitudes have lighter skin- their skin produces less melanin.

1. What forces of evolution are at work? Tick all that apply.

    ___ Mutation

    ___ Natural Selection

    ___ Genetic Drift

    ___ Gene Flow

2. Specifically, how is natural selection involved?
3. Explain how the forces of evolution shift allele frequencies in the population over time. Your answer should include all of the 'forces' of evolution that you identified as being employed (above). Put this information into a narrative to explain how new traits are introduced, how individuals are selected (if present), and how alleles in the population shift over time.

The Forces of Evolution Cards

Please print encough cards so that each student group has one of each type: Natural Selection, Mutation, Genetic Drift, and Gene Flow. Print each type on a different colored paper (e.g. Natural Selection cards are all yellow, Gene Flow cards are all Blue).

Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.		**Natural Selection** The process by which biological variation (adaptations) becomes more common in a population over generations.
Natural Selection The process by which biological variation (adaptations) becomes more common in a population over generations.		**Natural Selection** The process by which biological variation (adaptations) becomes more common in a population over generations.

Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.		**Mutation** Chemical change in the DNA. It can be positive, neutral, or deleterious.
Mutation Chemical change in the DNA. It can be positive, neutral, or deleterious.		**Mutation** Chemical change in the DNA. It can be positive, neutral, or deleterious.

Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.		**Gene Flow** Transfer of genes across population boundaries because their members are breeding with one another.
Gene Flow Transfer of genes across population boundaries because their members are breeding with one another.		**Gene Flow** Transfer of genes across population boundaries because their members are breeding with one another.

Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.		**Genetic Drift** When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.
Genetic Drift When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.		**Genetic Drift** When “random” factors cause a change in allele frequency over time. These factors have nothing to do with genetic health or an organism’s fitness for its environment.

CHAPTER OVERVIEW

5: Meet the Living Primates

Learning Objectives

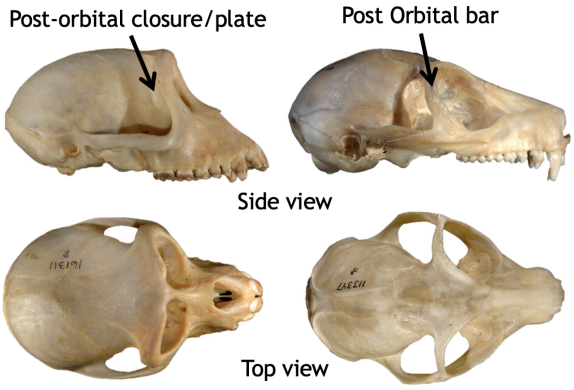
- Explain the form and function of primate features
- Discuss and depict the primate order and suborders

Thumbnail: Side and top views of postorbital closures and bars.

5.1: Primate Classification

Primate Classification

Format: In person or online



Side and top views of postorbital closures and bars.

Author: Beth Shook

Modified from labs by Henry M. McHenry, University of California, Davis

Time needed: 50-60 minutes

Supplies Needed

- Primate and non-primate skeletons and skulls. These can be real, casts, or images. A list is provided below.
- Labels for the skeletons and skulls (e.g., Primate or Strepsirrhine)
- Resources for students to look up specific examples of Platyrrhines (e.g., Rowe. 1996. *The Pictorial Guide to Living Primates*)
- Student worksheet (attached)

Readings

- Etting, Stephanie. 2019. Chapter 5: Meet the Living Primates. *Explorations*.

Introduction

People belong to the zoological order *Primates*, which is one of the many orders within the class *Mammalia*. This lab gives students the opportunity to observe characteristics of the skeleton that differentiates primates from other mammals and compare primates to one another.

Before beginning, students should consider the following conceptual questions: What can bones tell us about the animal to which they belonged? Specifically, what might the skeleton tell us about:

- what the animal ate?
- its mode of locomotion?
- the environment it lived in?
- its behavior?

Bones can reflect the lifestyle of primates, and the characteristics they share are likely reflective of early primate ancestors. For example, most primates move about in trees by grasping with their feet and hands. Primatologists believe the common ancestor of all living primates was an *arboreal* climber with *prehensile* extremities who relied on vision more than olfaction (smell). This ancestor may have had some depth perception, made possible by the overlapping visual fields of forward-facing eyes, and hands with the ability to manipulate objects. Thus, physical traits that help us distinguish primates from other mammals include:

- a generalized skeletal structure for arboreal life;
- convergent eyes (forward facing);
- eye orbits with a postorbital bar or plate;

- reduced snout length (related to less reliance on smell);
- opposable thumbs and big toes;
- flattened nails instead of, or in addition to, claws;
- a larger brain size;
- differences in tooth morphology (reflects variable diets);
- and prehensile (grasping) hands and feet.

Steps

- Before beginning this lab, the instructor should select skeletal materials, casts, or images of skeletal materials for students, and arrange them at various stations. All skeletal materials should be labeled with cards/small labels with terms that match the student worksheets (e.g., Primate, Strepsirrhine). Alternatively, virtual images can be
- linked to the student worksheet to create a virtual lab. Materials include non-primate, nonhuman primate, and primate skulls and articulated skeletons. Specifically:
  - Station 1: (a) primate (e.g., monkey) articulated skeleton, and (b) non-primate (e.g., cat or dog) articulated skeleton. Preservation should be good enough to see nails/claws.
  - Station 2: (a) non-primate (cow or pig) skull with teeth, (b) dog skull with teeth, (c) monkey skull with teeth, and (d) human skull with teeth. Be sure that the surfaces of the teeth are visible in addition to the eye orbits (e.g., the mandible can be separated from the skull or there are multiple images to depict various views).
  - Station 3: (a) strepsirrhine (e.g., lemur) and (b) haplorrhine (e.g., monkey).
  - Station 4: (a) tarsier. Because this station asks students whether the tarsier is more like a strepsirrhine or haplorrhine for given traits, they should have either completed Station 3 or have access to comparative materials at this station too. Additionally, because tarsiers are small, it can be difficult for students to clearly identify some of the traits, and it can be useful to also provide a diagram with a closer view.
  - Station 5: (a) New World monkey skull and (b) catarrhine skull (preferably an Old World monkey). Be sure to use adult primate skulls so that students can accurately compare their dental formulas. Additionally, this station requires photographs of these primates so that students can compare nose shapes and look up examples of different types of New World monkeys.
  - Station 6: (a) Old World monkey articulated skeleton, (b) ape articulated skeleton, and (c) human articulated skeleton. This station also asks students to compare molar cusp patterns, so it can be useful to also have separate skulls or photos of dentition.
  - Station 7: No skeletal materials are required. However, students should have completed Stations 3 through 6.
- The instructor should choose to assign this lab as an individual or small group activity.
- An introduction to encourage students to think about “form and function” of the skeleton would be helpful. Additionally, students should be encouraged to think broadly (incorporating what they already know about animals, what they eat, and how they move), especially when answering questions at Stations 1 and 2. Instructors should be sure students are familiar with the traits in the lab (e.g., foramen magnum, tooth comb, Y5 or bilophodont molar cusp patterns) or are given resources to identify these traits at the various stations.
- The lab consists of seven “stations.” Stations 1 and 2 focus on “form” and “function” of the skeleton, while stations 3 through 6 focus on the organization of the primate taxonomy. Students will rotate through stations filling out tables and answering questions on their worksheets. Instructors may assign some or all stations. Stations can be
- completed in any order, however Station 7 requires the completion of stations 3 through 6 first.
  - Station 1: Students compare **primate and non-primate postcrania** and relate the form of the skeletons to their function.
  - Station 2: Students compare **primate and non-primate teeth and crania** and relate the form of the skeletons to their function.
  - Station 3: Students compare **strepsirrhines and haplorrhines**.
  - Station 4: Students identify **tarsier** traits and evaluate their classification.
  - Station 5: Students compare **New World monkeys to catarrhines**.
  - Station 6: Students compare a **cercopithecoid to two hominoids (an ape and human).**
  - Station 7: Students construct a **primate order phylogeny** based on the information from Stations 3 through 6.
- Instructors should have students report to the class on their answers for some/all of the stations. For example, each group could complete a small table for one station on the board. While some parts of the tables are more open-ended, there are some traits that instructors will want to be sure students identified correctly.

Conclusion

By completing this lab, students learn to distinguish primate and non-primate body forms and functions, with a focus on postcrania, teeth, and eye orbits. Students learn how to differentiate the primate suborders (*Haplorrhini* and *Strepsirrhini*) and to describe the unique characteristics of tarsiers, New World primates, and Old World primates. By the end of this lab, students will have acquired a robust understanding of primate classification.

Adapting for Online Learning

This activity could be easily adapted to online classes by linking to 3-D images of primates at educational sites (e.g., eSkeletons) and students could share their results in an assignment, virtual meeting (e.g., Zoom), or on an LMS discussion board.

For Further Exploration

David Attenborough. 2003. "Episode 9: The Social Climbers." *The Life of Mammals* (Film) *eSkeletons*. Department of Anthropology, University of Texas at Austin. http://www.eskeletons.org/

2011. Primates—What is a Primate? *Odyssey Earth*. https://www.youtube.com/watch?v=BpnlS_ach-0&t=67s

Rothman, Jessica (editor). 2014. The Living Primates. *The Nature Education Knowledge Project*. https://www.nature.com/scitable/knowledge/the-living-primates-98011684/

Rowe, Noel. 1996. *The Pictorial Guide to Living Primates*. Charlestown: Pogonias Press.

References

Etting, Stephanie. 2019. "Chapter 5: Meet the Living Primates." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Primate Classification Worksheet

Introduction

People belong to the zoological order *Primates*, which is one of the many orders within the class *Mammalia*. This lab provides the opportunity to observe characteristics of the skeleton that differentiate primates from other mammals, and compare primates to each other.

Before beginning, consider the following: What can bones tell us about the animal to which they belonged? Specifically, what might the skeleton tell us about:

- what the animal ate?
- its mode of locomotion?
- the kind of environment it lived in?
- its behavior?

Bones can reflect the lifestyle of primates, and the characteristics they share are likely reflective of early primate ancestors. For example, most primates move about in trees by grasping with their feet and hands. Primatologists believe the common ancestor of all living primates was an *arboreal* climber with *prehensile* extremities, who relied on vision more than olfaction (smell). This ancestor may have had some depth perception made possible by the overlapping visual fields of forward-facing eyes, and hands with the ability to manipulate objects. Thus, physical traits that help us distinguish primates from other mammals include:

- a generalized skeletal structure for arboreal life;
- convergent eyes (forward-facing);
- eye orbits with a postorbital bar or plate;
- reduced snout length (related to less reliance on smell);
- opposable thumbs and big toes;

- flattened nails instead of, or in addition to, claws;
- larger brain size
- differences in tooth morphology (reflects variable diets);
- and prehensile (grasping) hands and feet.

Station 1: Primate Versus Non-Primate Postcrania

Look at the skeletons or skeletal images provided. Note how the postcrania (body) of primates and non-primates differ. Carefully examine the vertebral column (backbone), the structure of the shoulder and pelvis, the shape of the rib cage, and the hands and feet. Think about what you already know about their locomotion and behavior for clues about how they move and the differences you may see on their skeleton. Record general observations in the table below.

	Non-Primates (Ex. dog, cow, pig)	**Primates (Ex. monkey)**
Hands and feet		
Claws or nails		
Vertebral column and rib cage		
Clavicle		
Pelvis		

How do the above characteristics suggest the locomotion and posture of primates differ from non-primates?

Station 2: Non-Primate and Primate Teeth and Skulls

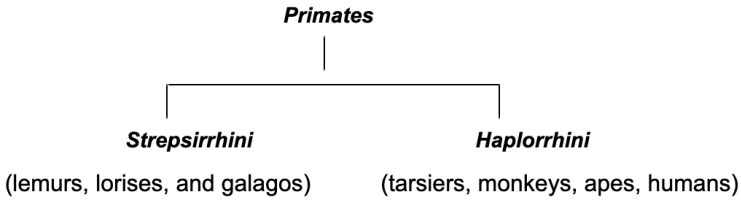
Mammals typically have four different kinds of teeth: *incisors*, *canines*, *premolars*, and *molars*. Examine the teeth of the primates (monkey and human) and non-primates (cow or pig and dog). While they all have a mixture of incisors, canines, premolars, and molars, what differences do you see between the species? (Number of teeth? Shape? Cusp pattern?) What might these features tell us about their function?

	Non-Primates		**Primates**	
	Cow/Pig	**Dog**	**Monkey**	**Human**
Distinguishing features of the teeth				
Draw the tooth row shape				
Probable diet				

The *orbit* is the bony structure that protects the eye. All living primates have a complete bony ring around the eye, but the orbit can be either open (postorbital bar) or closed (postorbital plate) in the back. Examine the orbits and their orientation. What differences do you see? Look at the *foramen magnum*: What does this tell you about the typical posture of the animal? Finally, look at the *nasal region*. Does this tell you about what senses they use most?

	Non-Primates		**Primates**	
	Cow/Pig	**Dog**	**Monkey**	**Human**
Eye orbit structure and orientation				
Foramen magnum position				
Size and complexity of nasal region				
Rely more on vision or smell?				

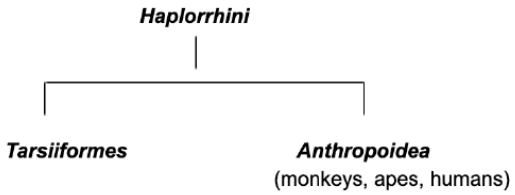
Station 3: Primate Suborders: *Strepsirrhini* and *Haplorrhini*



Most modern strepsirrhines live on the island of Madagascar (lemurs), but a few stalk the night forests of Africa (galagos) and Asia (lorises). Our own suborder (haplorrhines) live in Asia, Africa, and the Americas. It is easy to talk about ourselves as if we are higher, grander, further up the scale, etc., but evolution results from adaptation to the immediate environment without a predetermined direction. So don't be specio-centric! After all, *Loris tardigradus* (a strepsirrhine) is much cuter than *Cacajao rubicundus* (a haplorrhine)!

	Strepsirrhine	**Haplorrhine**
Nails or claws? Which digits?	Claw on second digit, nails on others	Nails only
Postorbital bar or plate?		
Orientation of eye orbits (forward or toward the side)		
Snout length relative to brain size		
Presence or absence of tooth comb		
Geographic location (read intro above)		

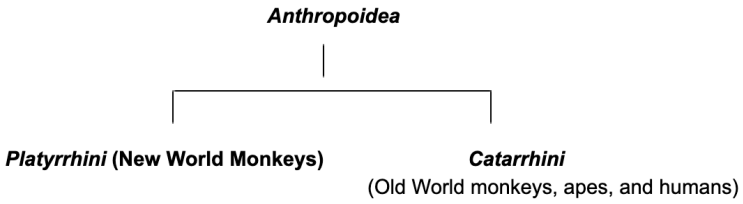
Station 4: Tarsiers



For some time, tarsiers challenged primatologists with regard to their classification: Were they closer to monkeys, apes, and humans or closer to lemurs and lorises? Genetic evidence has now provided strong support for the classification of tarsiers as haplorrhines, but their ancestors likely split off early, before the division of different types of monkeys and apes. Examine the tarsiers—what traits may have been confusing to primatologists because they are similar to lemurs and lorises or are unique to the tarsier?

	Tarsier	**Is this trait more like strepsirrhines or haplorrhines, or is it unique?**
Nails or claws? Which digits?	Grooming claw, and nails on other digits	
Postorbital bar or plate?		
Orientation of eye orbits (forward or toward the side)		
Snout length relative to brain size		
Presence or absence of tooth comb		
Geographic location	Asia	N/A

Station 5: New World Monkeys



Anthropoids are divided into two infraorders: *Catarrhini* (Old World monkeys, apes, and humans, all who live in Africa and Asia) and *Platyrrhini* (New World monkeys who live in Mexico, Central, and South America). The word "monkey" is confusing because monkeys in the Americas are not closely related to Old World monkeys (Old World monkeys are, in fact, more closely related to people!)

	New World Monkey	**Catarrhine**
Meaning of scientific name	"Broad-nosed" (separated by wide nasal septum)	"Hook-nosed" (nostrils are close together)
Direction nostrils face	*Look at photographs*	*Look at photographs*
Dental formula		
Geographic location (read intro above)		

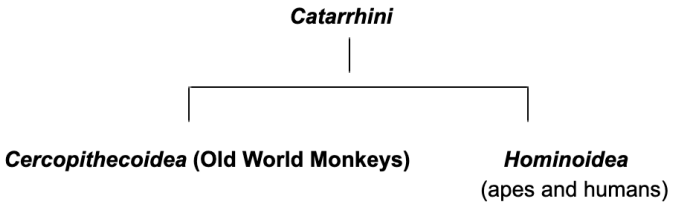
Questions:

Some New World monkeys (*Atelinae)* have prehensile tails. Look up the name of one monkey that has a prehensile tail: _____

One group of New World monkeys, *Callitrichidae* (marmosets and tamarins), have re-evolved claws on all but one digit. Which digit? (Do some research to find out!) _____

There is one group of New World monkeys who have a reduced or absent thumb. What type of monkey is this? _____

Station 6: Old World Monkeys and Hominoids



	Cercopithecoid	**Hominoids**	
	Old World Monkey	**Ape (e.g., chimpanzee)**	**Human**
Shape of rib cage			
Length of forelimb (arm) relative to trunk			
Length of clavicle and location of scapula			
Presence or absence of tail			
Lower molar cusp pattern (Y5 or bilophodont)			

The differences between the monkey skeletons and the hominoids may be because the common ancestor of apes and people was adapted for suspending the body by the arms and *brachiating*. The forelimbs are long, the shoulders are flexible, the elbows and wrists allow greater rotation, the chest is wide for the attachment of expanded forelimb retractor muscles, and the lower back is short. Cercopithecoids, on the other hand, are adapted to quadrupedalism, like most mammals. The bilophodont molar is their specialization for eating a wide variety of foods.

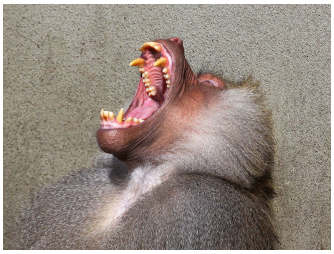
Station 7: Putting It All Together

Using what you have learned at Stations 3 through 6, construct the complete tree for the *Primates* order. Put primates at the top, divide them into strepsirrhines and haplorrhines, and then work your way down, dividing them into subgroups as you go. Use the tree in your textbook if you need help. **Then, for each group on the tree identify at least one trait that helps distinguish that group.**

5.2: Primate Tweets

Primate Tweets

Format: In-person or online



The open-mouthed Hamadryas baboon reveals the diastema between his upper canine and front teeth.

Author: Kristen Broehl

Time needed: 60-90 minutes

Learning Objectives

- Identify primate anatomy and behavior
- Accurately describe a primate species

Supplies Needed

- Student worksheet and checklist

Readings

- Etting, Stephanie. 2019. Chapter 5: Meet the Living Primates. *Explorations.*

Introduction

For this activity, students develop a tweet from the perspective of a primate. The tweets can be in a variety of formats – some may use tweets simply to tell about their day while others use tweets to share creative content. Students have leeway with the type of tweet they write, so long as they follow the guidelines on the worksheet below, including the 280 character limit. The use of relevant images, gifs, memes, emojis, hashtags, etc. is encouraged.

Example 5.2.1 by Rose Perash

Some tweets provide life updates. This example conveys that the primate, aye-aye, has rodent-like teeth, eats grubs, and is nocturnal:

> Long night at the office! Feeling as worn down as my rodent-like teeth. Time to nab a few grubs and head to bed before sunup! #yum

Example 5.2.2

Some tweets include variations of the “roses are red, violets are blue” poem. This tweet conveys that the primate, tarsier, is nocturnal, has long tarsals, uses clinging and leaping for locomotion, has huge eyes, and is carnivorous:

> Roses are red
>
> At night I’m not sleeping
>
> I’ve got super long tarsals
>
> For clinging and leaping
>
> Violets are blue
>
> My eyes make up much of my head
>
> I’m completely carnivorous

So this lizard is dead

Example 5.2.3

Some tweets recount conversations someone witnessed. This tweet conveys that the primate, gorilla, is polygynous, eats bamboo leaves, males are silverbacks, weigh around 400 pounds, and use knuckle-walking locomotion:

Primate domestic dispute:

Mom: You don't need another wife

Dad: *stares at her while eating bamboo leaf*

Mom: You already have so many your hair is turning silver!

Dad:….

Mom: …

D: …There's 400 lbs of me, enough to go around. *Turns away*

M: Don't you knuckle-walk away from me!

Steps

- Write primate names (gorilla, chimpanzee, tarsier, ring-tailed lemur, etc) on the questionnaire sheets and then draw student names to set partners.
- Randomly distribute the sheets to the pairs, so that partners and primates are randomly assigned.
- Ask students to fill out the questionnaire sheet for their primate based on lecture/lab notes, textbook, and websites provided (see "For Further Exploration" below). Some traits on the sheet won't be relevant to every primate; students can insert N/A as appropriate. Using this information, students will then create tweets, following the instructions on the activity sheet.
- Read or display tweets, and ask other students to guess which primate it describes, or have students post their tweets on an online discussion board so other students can "reply" with their guesses.

Review Questions

1. What are common primate characteristics?

2. Which kinds of traits (e.g. physical, behavioral, etc.) make it easier or more difficult to correctly identify the primate?

3. When observing a primate at the zoo or in the wild, which characteristics do you think would be most helpful for correctly identifying the species?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

If applicable, include tips and suggestions on how to adapt this lab for online learning: For online classes, students can complete the activity individually or in pairs, post their tweets to a discussion board in the course's Learning Management System, and then comment on other students' tweets with their guesses for which primate is represented.

For Further Exploration

This website provides information about various primates: http://pin.primate.wisc.edu/factsheets

Image Attribution

Primate Tweets Worksheet

Name: _____

Partner Name(s): _____

Primate: _____

For this assignment, you will be writing a tweet about a primate. The point is to make the tweet educational *and* creative. You will include a number of facts about your assigned primate, but don't say what the primate is so that your classmates can guess later!

Purpose:

This assignment will serve as a review of important aspects of each primate's anatomy and behavior. Since it cannot be longer than a tweet (maximum 280 characters, including spaces), you will be forced to choose only a few details to incorporate, meaning you will need to decide which facts are most important. Creative content can also be easier to remember, so try to make these tweets clever or funny enough to stand out in your classmates' minds!

Directions:

First, work with your partner to fill out the questionnaire sheet. This can help you organize your thoughts and decide which facts are significant enough to be included in your tweet. At the end of class, I will ask you to turn in these sheets. Once you have filled out the fact sheet, compose a tweet including some of the information from the questionnaire. Be creative! You can use memes, emojis, poems, rhyming, common tweet formats, jokes, humor, sarcasm, hashtags, etc. However, do not include the name or a picture of your primate – students should be able to guess the primate from the information you provide in your tweet.

Your tweet should include *at least* three facts about your primate. Of these three facts, at least one should be about anatomy and one should be about behavior. The other details could be about any other aspect you choose. Also, one of the facts should be something completely unique about your group/clade. Note that your assigned primate may include many species with slightly different anatomy or behavior – in this case, consider what is typical or most common among the species. After you are finished creating your tweet, submit it either in class or online.

Use the checklist on the back of this page to make sure you included all necessary elements, and then answer the questions below it about group work.

Checklist:

____ Questionnaire completed thoroughly.

Tweet…

____ Is no more than 280 characters, including letters, punctuation, spaces, etc.

____ Conveys a *minimum* of three facts about assigned primate.

____ Includes at least one fact about the primate's behavior.

____ Includes at least one fact about primate's anatomy.

____ Includes at least one fact that is a unique feature of primate's anatomy or behavior.

____ Does not include the name or picture of the primate.

____ Creatively conveys the information.

Briefly describe your personal contributions to the assignment.

Briefly describe your partner's contributions to the assignment.

Names _____

Primate: _____

Classification (terminal branch from primate phylogeny): _____

Anatomy Unique?

Dental formula: _____ •

Features of dentition: _____ •

Traits of digits: _____ •

Traits of orbits: _____ •

_____ •

Traits of nose: _____ •

Body size: _____ •

Sexual dimorphism: _____ •

Other traits: _____ •

_____ •

Behavior Unique?

Habitat: _____ •

Locations: _____ •

Nocturnal/diurnal: _____ •

Diet: _____ •

Mating structure: _____ •

Social behavior: _____ •

_____ •

Locomotion: _____ •

Other traits: _____ •

_____ •

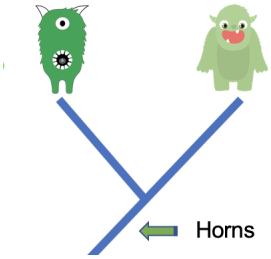
_____ •

_____ •

5.3: Creating a Monster Phylogeny

Creating a Monster Phylogeny

Format: In person or online



Part of a “monster phylogeny,” showing where horns evolved.

Author: Beth Shook

Time needed: 30-50 minutes

Learning Objectives

- Identify traits of characters and place them into a student-defined hierarchy to create a classification key
- Draw a corresponding phylogeny (evolutionary tree) for the characters
- Identify clades and corresponding primitive and derived characteristics using the phylogeny

Supplies Needed

- Ten imaginary character cards/tiles per group (each group can have the same set of ten or a unique assortment). Characters (attached) can be printed on cardstock or laminated, or tiles from a child’s memory/matching game can be used.
- Pencils with erasers
- Colored markers
- Blank paper
- Rulers (optional)
- Student worksheet (attached)

Readings

- Etting, Stephanie. 2019. Chapter 5: Meet the Living Primates. *Explorations*.

Introduction

A phylogeny is a diagram depicting evolutionary relationships among organisms (*taxa*). Phylogenies are sometimes referred to as evolutionary trees or cladograms. These “family trees” are developed based on analysis of physical traits, or, increasingly, genetic information, that provide clues about the evolutionary relationships between these organisms.

In this lab, students create a fictional phylogeny by first identifying traits shared among fictional characters and developing a (student-defined) classification key. Students then draw the phylogeny and identify common ancestors (nodes), contemporary *taxa* (tips), and clades. They mark where certain traits evolved on the tree. Lastly, students identify primitive and derived traits for some of the clades.

Steps

1. This activity may be assigned as either an individual or small group activity.
2. Instructors will distribute 10 character images to each student or small group. Each group can have the same set of 10, or each group can have a unique assortment of characters (this is often more enjoyable). Printables (attached) can be printed (on cardstock or laminated), or tiles from a child’s memory/matching game can be used. It is *not* recommended to use images of real animals as students may feel pressured to select the “right” biological answer. Instead, students should be encouraged to be creative.There is no perfect phylogenetic answer. This lab is more about experiencing the process and learning the concepts.
3. Before the activity, the instructor should spend some time introducing what phylogenies are and how they are drawn and labeled. Some of this information is provided in the “background” section of the student worksheet (attached).

4. The instructor should also review how to identify clades and primitive and derived characteristics. It can be beneficial to go through a simple example ahead of time, articulating the expectations for how to circle clades, write in where traits evolved, and identify primitive and derived traits.
5. Using the cards and the instructions in the student worksheet (attached), students develop a classification key and a corresponding phylogeny. This phylogeny should be appropriately labeled. Lastly, students will circle some clades and identify primitive and derived traits.
6. Instructors should collect the students' phylogenies to check for accuracy. Afterward, they should go through an abbreviated version of one of the phylogenies (or use the example attached) and check for students' understanding of primitive and derived traits. Do not reveal the example to the students before they turn in their phylogenies, as it may bias their work.

Review Questions

- What is the meaning of "phylogeny"?
- Which characteristics did you focus on when you were developing your tree? Why? In this case we don't know in what order the traits evolved in this group of *taxa* (they are fictional!). However, biologists want their phylogenies to reflect evolutionary history. What clues do biologists use to help them identify the order in which these traits evolved?
- How would your phylogeny change if you chose to focus on different aspects?
- What have you found to be the most helpful way to distinguish between primitive and derived traits for a given clade? Briefly describe how one trait on your phylogeny could be both a primitive and a derived trait.

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

This activity does not require many supplies and could be adapted for online classes if students can print and cut out the imaginary characters (attached) or move the digital images around in an electronic document (e.g., Google Slides). This activity can be difficult for some students new to these concepts, so it is important that students follow the order of the steps and ask questions during the process. It is best to do this activity during a synchronous online session (live with an instructor) or provide a demonstration first.

For Further Exploration

The Understanding Evolution team. Phylogenetic systematics, a.k.a. evolutionary trees.

https://evolution.berkeley.edu/evolibrary/article/0_0_0/phylogenetics_01

References

Etting, Stephanie. 2019. "Chapter 5: Meet the Living Primates." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

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Red Oso, by rMiszczak, is in the public domain.

Blue One-eyed Monster, by dcorbridge, is in the public domain.

Public Monster with Antlers, by dcorbridge, is in the public domain.

Green Monster by F.M., by dcorbridge, is in the public domain.

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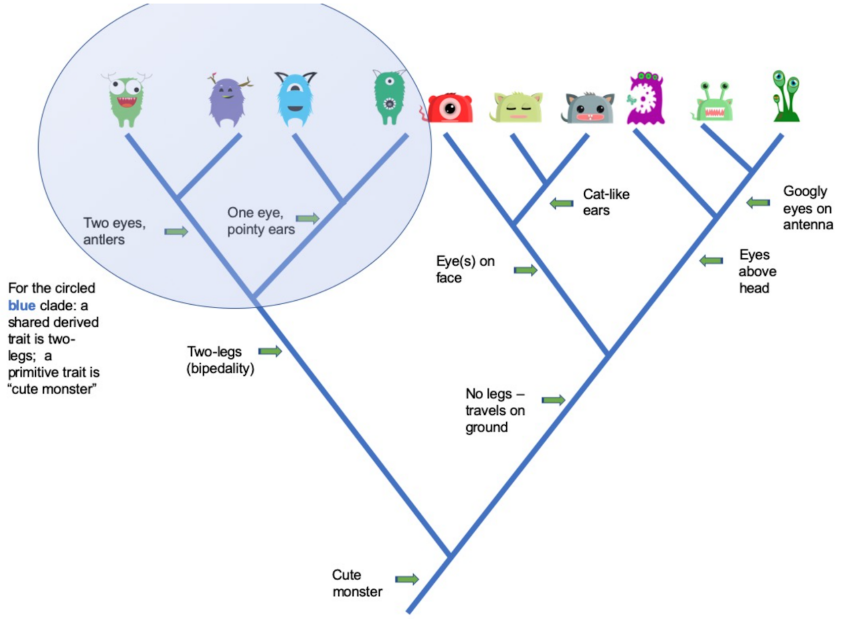
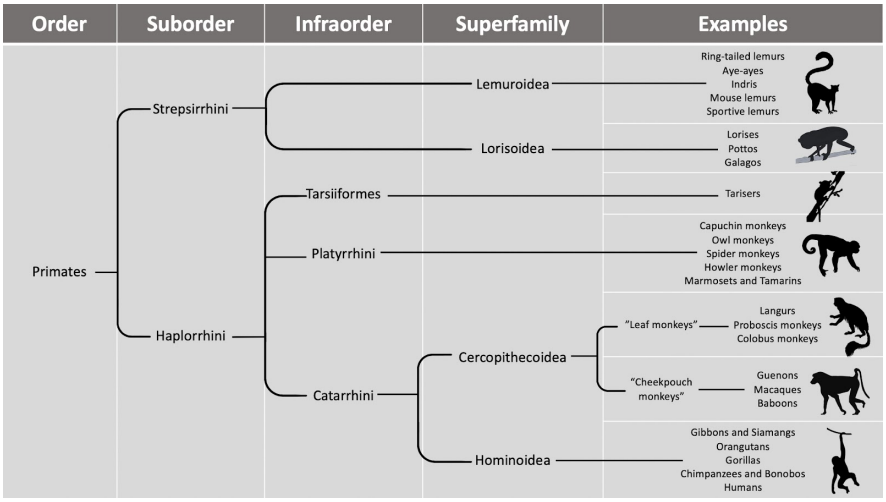
Example Phylogeny for Instructor



Creating a Monster Phylogeny: Worksheet

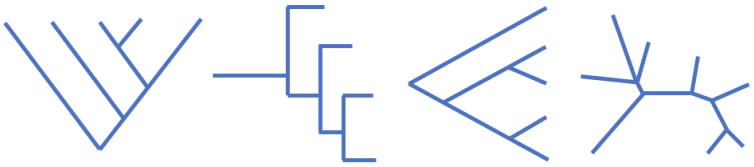
Background

A phylogeny is a diagram depicting evolutionary relationships among organisms (*taxa*). Phylogenies are sometimes referred to as evolutionary trees or cladograms. These "family trees" are developed based on analysis of physical characters, or, increasingly, genetic information, that provide clues about the evolutionary relationships between these organisms. An example phylogeny of the order *Primates* is provided below.

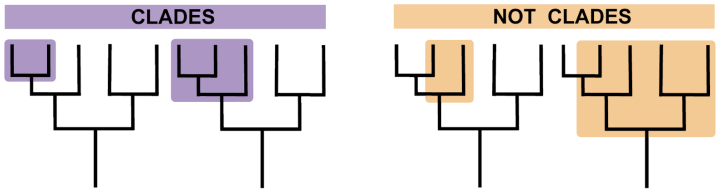


Each of the tips of the phylogeny represents a type of organism (*taxon*, singular for *taxa*). These are usually different species, but could be individuals. A *node*, where a phylogeny branches into two (or more) descendant branches, represents a common ancestor. Typically those in the field of cladistics (who create and study evolutionary trees and clades, as defined below) assume that when a lineage splits, it splits into exactly two groups. However, sometimes the data is insufficient to identify in which order the splits occurred.

Phylogenetic trees can be oriented in various directions, with the common ancestor at the bottom, side, or even spiraling out from the center.



Phylogenetic trees depict *clades*. A clade is defined as a common ancestor and **all** of its descendants (living and extinct). Phylogenies will include many clades—often with clades nested inside of other clades. In fact, the entire tree can be conceptualized as one clade—since they all share one common ancestor. Thus, when describing part of a phylogeny, it is important to clearly identify which clade is being discussed—members of a clade will often share a scientific name.



Cladistics assumes that characteristics (physical and/or genetic) will change over time. It is when these traits change that we are able to differentiate between lineages or groups. The original form of the trait (held by ancestors and relatives outside a designated clade) is considered "*primitive*" or *plesiomorphic*. Be careful not to assume primitive traits are more simple or inferior, though, as evolution does not imply improvement or increased complexity! Changed traits are referred to as "*derived*" or *apomorphic*. All members of a clade can be distinguished from all other *taxa* in the tree because they inherited a *shared derived trait* or traits that were novel to the common ancestor of that clade.

Steps

For this activity, you will use the 10 imaginary characters provided for you, to create a classification key and a corresponding phylogeny. You will need a couple sheets of blank paper, a pencil with an eraser (to draw your phylogeny and erase/move lines, if needed), and colored pens, to complete the activity.

To Build the Classification Key

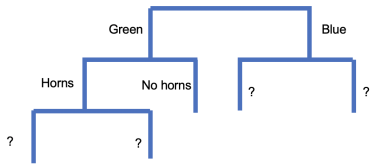
1. Lay out the 10 characters in front of you. Identify a character trait(s) that divides the 10 characters into two groups, for example: two legs versus four legs or green versus blue. The 10 characters do not need to be divided exactly in half; dividing them into one small and one large group based on the trait you select is equally fine. The precise trait(s) you select is not critical for this activity; what matters is that your categorization is strong. **Take careful notes along the way to document the new groups you made and the traits you used to divide them.**

   Example: Green versus Blue 

2. Repeat the process with each of the small groups, selecting a new trait each time. For example, you could now divide the green group by those with horns and those without. The number of individuals in each group does not matter—a group of five could be divided into one and four, or two and three. **Again, take careful notes along the way to document the new groups you made and the trait(s) you used to divide them.**

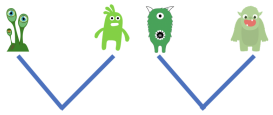
   Example: Horns versus No Horns 

3. Continue dividing up all subgroups with two or more imaginary characters until each individual can be classified as unique by the traits it possesses. Again, take careful notes along the way!
4. Now write out a simple key—it does not need to be perfect but it must be legible and clearly represent each of the divisions of your characters. At the bottom of the key, where all individuals have been separated, it may be helpful to give each character a name to help you distinguish it on both the key and the phylogeny. Here is an example of a key. Be sure to include the derived traits that you use to divide your characters next to the brackets.

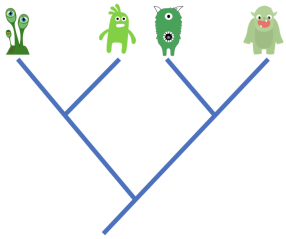


To Build the Phylogeny

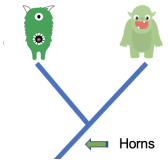
5. Using a pencil and a new blank sheet of paper organized on a landscape layout (so the long edge is horizontal), list all 10 characters across the top of the page in the same order that they were at the bottom of your key (left to right). You may draw them or use an identifying name (e.g., green three-eyed monster).
6. Starting just below the characters, draw lines down to connect the characters who are most closely related (share the most traits and were the last to be separated in the key.)



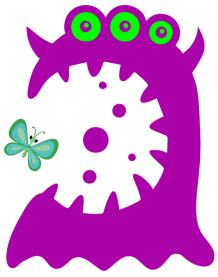
7. Continue connecting individuals/groups (at their node) to complete the phylogeny.

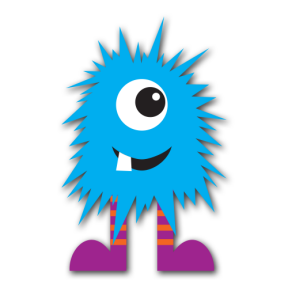


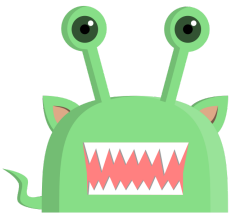
8. Label the phylogeny with all the traits from your key approximately where they evolved (just below the last common ancestor node).

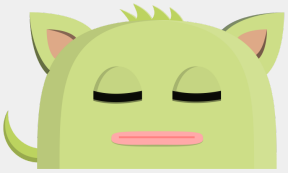
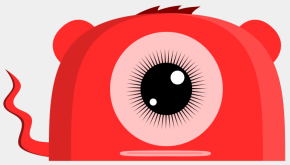
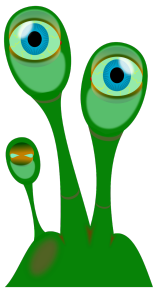


9. Using three different colored markers, draw a circle around three distinct clades (one color for each clade).
10. To the side, or on the back of your finished phylogeny, answer the following questions based on your tree.
    a. Define clade.
    b. What are represented by the tips of the phylogeny?
    c. What are represented by the nodes of the phylogeny?
    d. For each of the three clades, name a *shared derived trait* and a *primitive trait*. Please record the color and corresponding trait; for example: *For the red clade, a primitive trait is three teeth and a shared derived trait is fur.*
    e. Are there any traits from your phylogeny that were identified as a primitive trait for one clade and a derived trait for another clade? Why does this occur?
11. When you are finished, label your phylogeny with your name and submit it to your instructor.

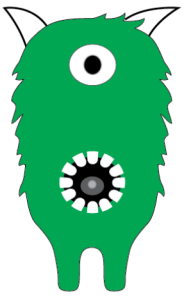








5.4: Modern Primate Museum

Modern Primate Museum

Format: In person or online

See tarsiers in a virtual museum of anthropology.

Author: Dr. Keith Chan

Time needed: ~30 minutes

Learning Objectives

- Identify scale models of modern primates
- Examine traits of modern primates
- Infer the adaptations of modern primates

Supplies Needed

- Computer, smartphone, or VR goggles (optimal)
- Internet connection
- AnVRopomotron.com
- Worksheet (attached)

Readings

- Etting, Stephanie. 2019. Chapter 5: Meet the Living Primates. *Explorations*.

Introduction

In this activity we will look at exhibits in AnVRopomotron.com, an online virtual anthropology museum created by Dr. Keith Chan. Our focus will be on modern primates: examining their skulls and other physical traits. Students will answer questions by finding information presented in the virtual museum along with their own thinking about the lives of primates living today, based on lectures and readings.

AnVRopomotron can be viewed on web browsers in a variety of devices with different control schemes. A computer with a mouse and keyboard will provide a good experience. A smartphone with touch controls is less ideal due to the small screen. A virtual reality headset with touch controls is optimal when virtual reality goggles are available.

Steps

1. Students could work individually or in teams, but be sure to each take turns in order to experience the museum if working in a group.
2. Part 1: Students load the AnVRopomotron website and use their controls to go right and behind the wall to the “Grab Lab.” Students should browse the two tables from the right, “Modern Hominid Skulls” and “Modern Prosimian and Monkey Skulls.” They can interact with each object to bring up info boxes to help them answer the questions on the worksheet.
3. Part 2: Students will leave the “Grab Lab,” walk past the Height Chart, and into the Scale Model Hall. That section has models of modern primates, including tarsiers, gorillas, and a howler monkey. More orange orbs bring up information on each species to help students answer the questions on the worksheet.

Review Questions

The activity allows students to visualize prehistoric primates in a way that is connected to their own perception and exploration. Here are some areas to direct a discussion at the conclusion of this lab:

1. Discuss traits that the primates share in common and how they differ.
2. What was surprising about the traits of the skulls and the scale models?
3. What are some examples of primate adaptations to specific environments?

Adapting for Online Learning

Rank how adaptable to online learning this lab is:

If applicable, include tips and suggestions on how to adapt this lab for online learning: Students could browse the exhibits and answer the questions on their own using their own device.

Tips and Suggestions

Browse the AnVRopomotron.com site on your own to get used to the controls and the layout of the museum. Students into gaming should be able to pick up the controls quickly but others may need help.

References

Etting, Stephanie. 2019. “Chapter 5: Meet the Modern Primates.” *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Chan, Keith. (2021). Tarsier [Illustration]. Used under Creative Commons 0: Public Domain Dedication.

AnVRopomotron Worksheet

Introduction

Go to anvropomotron.com on your device and use the controls to move around. The different controls for different devices are listed on the wall you are facing:

- Computer web browser: Use the WASD keys to move and drag with the mouse to look around.
- Smartphone: Press on the screen to move forward. Press with two fingers to move backward. Enable motion controls to tilt your phone to look around. Otherwise, swipe with your finger to look.
- Virtual Reality: Use the left thumbstick to move and the right thumbstick to turn. Pushing forward on the right thumbstick activates a teleportation feature.

Part 1. VR Grab Lab

Facing the front of the bronze centerpiece, turn right and go into the VR Grab Lab. Go past the two artifact tables and turn the corner to face the back wall that features four more tables. We will be working with the two tables to the right, labeled “Modern Hominoid Skulls” and “Modern Prosimian and Monkey Skulls.” Touch the items to bring up information on the back wall and a magnified view. First, touch the modern human skull to the far right of the “Modern Hominoid Skulls” table. Then, answer these questions.

1. Compare this model with others on the table: What are some differences in the traits between the modern human skull and the others?

Now examine the chimpanzee skull next to the modern human one. Touch it to bring up its information.

2. What is the scientific name of the chimpanzee?

3. Where is the chimpanzee found in the wild?

The next two skulls to your left are the two biggest on the table. They belong to the same species, even though they have very different traits.

4. Which of the two big skulls is the larger of the two?

5. What is the term for the difference in size between males and females?

Move over to the next table to the left, labeled “Modern Prosimian and Monkey Skulls.” Skip to the second skull from the right: the mandrill.

6. The crests of bone on the cheeks of the male mandrill support the colorful pads of skin as seen in the photograph on the wall. The male mandrill has this trait to attract females. What do you think the female mandrill’s skull looks like in comparison?

Pick the small skull near the center of the table. It is the skull of a squirrel monkey.

7. What trait visible in the photograph of the squirrel monkey identifies it as a platyrrhine?

The two skulls on the far left belong to the potto and the indri. Examine each one.

8. What is one of the traits on these two skulls that is not present in any of the others on the table?

Part 2. Scale Model Hall

Walk out the way you came and then pass by the left side of the Height Chart to enter the Scale Model Hall. Keep turning left until you see a model of a gray monkey on a blue structure to your left. Touch its orb to bring up some information.

9. What is the scientific name of the monkey?

10. What is the object that the monkey model is standing on? How many times larger is the model compared to the real object it is based on?

Move on to the next display, which is a series of four tarsier models. Touch the orb near it for information.

11. What ability of the tarsier is the series of models showing?

Continue to the next set of models, showing gorillas and a mouse lemur. Touch the orb to show its information.

12. While they look very different, the eastern lowland gorilla and Madame Berthe's mouse lemur both share primate traits. What are two traits they have in common?

Just a fun fact: Madame Berthe's mouse lemur is named for Berthe Rakotosamimanana, a researcher from the lemur's home island of Madagascar.

13. Real gorillas and mouse lemurs do not live together. What is the display showing by putting them together?

Turn right from the gorillas and lemur display and move toward the large orange ape sitting on the ground. As usual, touch its orb to bring up its information.

14. What is the common name of this primate?

15. Why is this primate critically endangered?

Turn left to the next display, just to the left of the doorway to the Burial Chamber (which is not part of this assignment). Look at the black-and-gold howler monkey on the branch. Touch its orb for info. Bonus fact: The “gold” part of the species's name refers to the gold color of the female. The model is based on the male.

16. Based on the information, why do you think the howler monkey has an enlarged lower jaw and throat area?

17. Consider what you know about natural selection: How would these traits act as adaptations that increase reproductive success?

Part 4. Summary

Thinking about the exhibits you have seen, put some of the information together by answering the following questions.

18. Comparing skulls with the living forms, how could studying skulls give an incomplete view of the organism? In contrast, what does studying skulls contribute to our knowledge of primates?

19. How would you describe the diversity of modern primates, based on what you have seen? Consider both biology and behavior in your answer.

CHAPTER OVERVIEW

6: Primate Ecology and Behavior

Learning Objectives

- Understand ethology and its role in primatology
- Practice scientific observation of primate behavior
- Analyze findings and present them in an organized written report

Thumbnail: Primates exhibit complex behavior that can be interpreted through careful observation.

6.1: Watching Primates

Watching Primates

Format: Online

Author: Dr. Keith Chan

Time needed: 45 minutes

Supplies Needed

- Internet connection
- Access to YouTube
- Primate Observation Playlist
- Worksheet (attached)

Readings

- Jaffe, Karin Enstam. 2019. Chapter 6: Primate Ecology and Behavior. *Explorations*.

Introduction

This assignment has three parts that follow the scientific method: 1. Prepare for the observation; 2. Observe primates in videos; 3. Report the findings.

Steps

1. Students should work individually but can compare their observations and findings at the conclusion of the assignment.
2. In class (or online), the instructor should go over Part 1 to make sure that students are adequately prepared to move to Part 2. Instructors and students may choose to brainstorm more behaviors to add to the ethogram.
3. Part 2 is intended for students to do on their own at home, although it can be adapted for an in-person lab.
4. Part 3 is also intended for homework as it involves independent report writing.
5. After the activity, the instructor can lead a discussion on what the students experienced and what they learned about primate behavior.

Review Questions

The activity gives students experience observing animal behavior and recording data scientifically. Here are some questions for discussion after the activity:

1. What were some behaviors that surprised the students?
2. What challenges arose during the observation?
3. Did all students observe the same things from the same video or did some students observe different things? Why would different observations occur?
4. What are some benefits and drawbacks of scan sampling versus focal sampling?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it is (mark in bold):

If applicable, include suggestions for how to adapt this lab for online learning: Students could watch the videos and complete the observation tables online. Instructors could set up an online discussion for students to share their results and comment on their classmates' results.

Tips and Suggestions

Personalize this activity with your own recorded videos or use of a livestream.

References

Jaffe, Karin Enstam. 2019. "Chapter 6: Primate Ecology and Behavior." *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

SVG SILH. (n.d.). animal gorilla ape [Illustration]. Retrieved from https://svgsilh.com/image/37835.html. Used under Creative Commons 0: Public Domain Dedication.

Watching Primates: Student Worksheet

Introduction

Legendary primatologist Jane Goodall revolutionized the study of chimpanzees during her fieldwork in Gombe, Tanzania. The behaviors she witnessed changed our perception of apes from instinct-driven creatures to tool-inventing beings.

In this activity you will learn about **ethology**, or how researchers turn observations of living things into scientific data, and then create a report of what you saw. While we cannot go to Gombe on short notice, we can watch uncut videos of zoo-dwelling primates online and apply scientific techniques to go beyond what a typical zoo visitor sees.

There are different ways to collect data on animal behavior. We will be practicing **scan sampling** whereby the observer records the behaviors of the group at set intervals. By contrast, **focal sampling** involves recording every action of one specific individual over a length of time.

Part 1: Preparation

Before watching primates, you have to prepare for what you expect to see in order to save time and effort later, when you are intently focused on your living subjects. First, pick one of the videos to observe from the Primate Observation Playlist.

1. Which video and which primate will you observe (focus on *one* individual)?

Apply the scientific method and make a prediction about what you will see. Answer the following question:

2. Which behaviors do you think you will see when watching the primate for 15 minutes?

Now set up an **ethogram**, which is a table used to record animal behavior. You will use this table while observing the primate in order to reduce writing and produce a standardized data set of what you saw. Put short descriptions of behaviors in the left column. Some have been added for you, but you should add more based upon your general knowledge of primate behavior.

Primate Ethogram

Behavior	**Time** (0:30-7:30)														
	0:30	1:00	1:30	2:00	2:30	3:00	3:30	4:00	4:30	5:00	5:30	6:00	6:30	7:00	7:30
Out of View															
Standing															
Sitting															
Sleeping															
Eating															

Behavior	**Time** (8:00-15:00)													
	8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00
Out of View															
Standing															

Sitting														
Sleeping														
Eating														

Part 2: Observation

Now it is time to use your ethogram to record primate behavior using the scan sampling method. Read these instructions in full before starting:

1. Play the video you chose in Part 1.
2. Using the video's timer or your own stopwatch app, keep track of the time.
3. Every 30 seconds, record the behaviors of the primates you see using the ethogram you set up in Part 1. Mark each square for each behavior you see at each time. If you are watching multiple primates, try to keep track of each one by using a short unique name for them.
4. End observation at 15 minutes.

Here is a sample table:

Behavior/Time	10:00	10:30	11:00	11:30	12:00
Out of View			B, C	A, B	C
Sitting	A, B	A, B	A	C	B
Sleeping	C	C			A

A: Adult male, B: Adult female, C: Juvenile

Part 3: Analysis and Report

Your data set allows you to quantify how much time each primate spent with each activity. For each individual, calculate how many times they were seen performing each behavior by filling out this table (if you observed more than one individual, there are additional Time Budget tables in the "Additional Documents" section of this worksheet):

Time Budget for Individual:

Behavior/ Calculation	Boxes Seen	Total Visible Times	Boxes Seen/Total Visible Times
Out of View			Not calculated
Standing			
Sitting			
Sleeping			
Eating			

See this example based on the adult male in the example ethogram:

Time Budget for Individual: A: Adult Male

Behavior/Calculation	Boxes Seen	Total Visible Times	Boxes Seen/Total Visible Times *100
Out of View	1	4	Not calculated
Standing	3		75%
Sitting	1		25%

With your data set and time budget in hand, craft a report of what you saw. Follow these instructions to write an effective report that is at least 500 words, well organized, and clearly written to best communicate your message. Your report should include the following sections:

1. Introduction: Which primate(s) did you observe? Was the video a live stream, in person, or prerecorded? What did you expect to see? End this section with a short summary of what you actually saw and whether it matched what you expected.
2. Body Paragraph 1: Tell the reader in more detail what you saw. Start with a description of the scene and the individual primates. Then describe the actions you saw in order, from beginning to end, like it's a story with a lot of detail.
3. Body Paragraph 2: Present your analysis of time budgets. How much time did each individual spend with each behavior?
4. Conclusion: Summarize your paper for the reader. Briefly restate what primate(s) you observed, what you expected to see, and what you actually saw.

Additional Documents: More Time Budget Tables

Time Budget for Individual:

Behavior/ Calculation	Boxes Seen	Total Visible Times	Boxes Seen/Total Visible Times *100
Out of View			Not calculated
Standing			
Sitting			
Sleeping			
Eating			

Time Budget for Individual:

Behavior/ Calculation	Boxes Seen	Total Visible Times	Boxes Seen/Total Visible Times *100
Out of View			Not calculated
Standing			
Sitting			
Sleeping			

Eating			

6.2: Primate Behavior Part I

Primate Behavior Lab: Part I

Format: In person or online

A group of gelada baboons grooming.

Author: Rebecca Frank

Source: “Activity 13.” 2019. Frank, Rebecca, Brian Pierson, Philip Stein. *LAVC Anthro 111 Lab Manual. 7th Edition*.

Time needed: 60-90 minutes

Learning Objectives

- Observe and describe nonhuman primate behavior
- Learn how to create and use an ethogram
- Practice ad lib study

Supplies Needed

- Paper, pencil, clipboard
- Stopwatch
- Requires zoo visit
- Student worksheet

Readings

- Jaffe, Karin Enstam. 2019. Chapter 6: Primate Behavior and Ecology. *Explorations*.

Introduction

It is not practical to illustrate the concepts of primate behavior by taking a trip to the Amazon forest or African savannas. Most zoos, however, exhibit primates that can serve as a laboratory for observing animal behavior.

The behavior of primates in captivity differs in some ways from their behavior in natural habitats. In captivity, social interactions are apt to be more frequent and more intense than they are in the wild (Patterson 1992: 3). Captive animals have a set diet and limited opportunities for natural foraging behavior. Long treks or attacks by predators do not occur in the controlled environment of a zoo. Captive animals may also display abnormal behaviors related to the stress of captivity that are not typical of wild populations (c.f. chimpanzees; Birkett and Newton-Fisher 2011). Observations of captive primates need to keep these issues in mind while also recognizing that most behavior in captivity is typical of wild groups of the same species (Birkett and Newton-Fisher 2011; Scott and Lockard 1999).

In this lab, students will go to the local zoo to observe primates. They will conduct an ad lib study and create an ethogram. Instructors may choose to assign this lab along with the “Primate Behavior Lab: Part II,” in which students use the ethogram they create in this lab while conducting scan sampling and continuous focal animal sampling.

Steps

- Students will go to the zoo, either in groups or individually, to conduct this lab.
- Students will record information about the enclosure and their observations on the student worksheet (attached). The worksheets include instructions to students.
- In addition to having students turn in the worksheet, instructors may initiate a class discussion for students to describe their experiences and observations.

Review Questions

1. How do we define and describe behavior when we study primates?
2. Define “ad lib study” and an “ethogram.”
3. What are the biggest challenges in observing primate behavior?
4. Which behaviors did you observe? What are some benefits and some drawbacks of collecting observations using this method?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

Tip: For online classes, students could complete observations at the zoo and turn in the worksheet online. It can also be interesting for students to observe humans with this very different frame. Many zoos with live-webcams that would allow students to observe a group of primates from home. See, for example:

- Chattanooga Zoo Tamarins
- Detroit Zoo Japanese Macaques
-
- Houston Zoo Gorillas
- PIN Common Marmosets
- Reid Park Zoo Lemurs
- San Diego Zoo Baboons
- San Diego Zoo Orangutans

References

Birkett, Lucy P. and Nicholas E. Newton-Fisher. 2011. “How Abnormal Is the Behaviour of Captive, Zoo-Living Chimpanzees?” PLoS ONE 6(6): e20101. https://doi.org/10.1371/journal.pone.0020101

Frank, Rebecca. 2019. “Activity 13.1: Ab Lib Study” and “Activity 13.2: Developing an Ethogram.” In *LAVC Anthro 111 Lab Manual*, *7th Edition*, edited by Frank, Rebecca, Brian Pierson, and Philip Stein.

Jaffe, Karin Enstam. 2019. “Chapter 6: Primate Behavior and Ecology.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Patterson, James D. 1992. *Primate Behavior: An exercise workbook*. Prospect Heights, IL: Waveland Press.

Scott, Jennifer and John Lockard. 1999. “Female dominance relationships among captive Western Lowland Gorillas: Comparisons with the wild.” *Behaviour.* 136(10/11), 1283–1310.

Image Attribution

Primate Behavior Part I: Worksheet

Instructions

It is not practical to illustrate the concepts of primate behavior by taking a trip to the Amazon forest or African savannas. Most zoos, however, exhibit primates that can serve as a laboratory for observing animal behavior.

The behavior of primates in captivity may differ from their behavior in natural habitats. Yet, comparative studies of captive and wild populations of the same species have demonstrated that, under ideal captive conditions, the qualitative aspects of behavior differ little from those observed in the wild. In captivity, however, social interactions are apt to be more frequent and more intense than they are in the wild. Of course, some situations, such as long treks or attacks by predators, will not take place in the controlled environment of a zoo.

When you first walk up to the enclosure, the behavior of the individuals may appear to be erratic and random. However, many of these behaviors are patterned responses to specific situations. You need to be patient. It takes time to recognize common behavior and to ultimately be able to interpret why certain things are occurring.

Behaviors are best seen and described as motor activities, that is, physical movements. A real danger is to read emotions and motivations into the behavior of nonhuman animals. Without being able to interview these primates, you really do not know what is

going on in their minds. The best you can do is to carefully and accurately describe the physical activity of the animals and note the context of that behavior.

As you observe your chosen primate group remember that you share a number of features, so avoid interacting with them. Your behavior might influence their behavior. Do not stare at primates, which can signal a threat. Do not attempt to get their attention with noises or movements. Remember, you are attempting to observe natural behavior.

1a. Ad Lib Study

The first type of study that you will do is an ad lib study**.** In this type of study, you write down your observations as a list of behavioral events. Use the worksheet (below). For each event, carefully describe what is occurring, who is involved (if two or more individuals are involved, note who initiates the activity and toward whom it is directed), and approximately how long the event lasts. You should also note the time an event begins and ends.

If too much is happening too quickly, do not panic. Instead, zero in on one event at a time, and don't worry if something else is happening elsewhere. If very little is happening, focus on providing more detail, such as where individuals are looking and what they are doing with their hands, feet, or faces.

As you write your notes, you will need to refer to individual animals. Use a code, referring to the adult male as AM, adult female as AF, infant male as IM, and so on. If there are two adult females in the cage, refer to them as AF1 and AF2. Or you can name each individual, but still use a short code.

Students frequently make two errors in doing an ad lib narrative.

Error 1: An ad lib narrative is *not* a summary. You are to write down everything (or as much as you can) that is happening as it happens, even if a particular behavior is repeated several times.

> In the following example there are four animals observed over a period of about four minutes.
>
> 1:23 AF1 is sitting and looking at the ground. She picks up seeds and grasses with fingers. 1:25 A number are collected. AF1 put seeds into her mouth.
>
> 1:26 AF1 Scratches self with left foot on left side of head. AF2 in back of cage is eating a long twig.
>
> 1:27 JM climbs on wire mesh and looks back at other animals. JM jumps down and begins eating grass. Moves grass aside to expose seeds.
>
> 1:30 JM grabs handful of grass in right hand and jumps up to overhanging branch. He hangs upside down pulling on the grass that has wrapped around the branch.
>
> 1:32 JM Suddenly jumps to the ground and resumes eating.
>
> 1:36 JM walks rapidly to AF2 and sits in front of her exploring food that she is placing in her mouth. AF2 pushes JM's hand away, turns back toward him.
>
> 1:40 JM runs to center of cage, picks up grass, leaps to overhanging branch.

Error 2: Unless you are successful in interviewing the animals, you have no way of knowing what they are thinking or why they are doing something. Many of their behaviors may resemble human behaviors, but that does not mean that we may interpret nonhuman primate behaviors as human behaviors. J.D. Paterson (1992: 3) writes:

"…one must be extremely careful not to impute human motives, emotions, or intentions to these animals. This is anthropomorphism and is an often-unconscious form of bias which is associated with anthropocentrism, the perspective which placed man *(Homo sapiens)* as the central and most important organism in existence. It ought to be clear after a few minutes that these primates are not little humans, and that even if the action does reflect the same emotion, motive, or intention as a human would express under the same circumstances, the observer cannot prove it."

1b. Developing an Ethogram

An ethogram is a catalog of the behaviors observed in a species. It takes many long hours of observation to develop a complete catalog; you will make a simple ethogram.

A problem in developing an ethogram is deciding how generalized or how specific each category and definition should be. Let us use play behavior as an example. One definition of social play behavior is: repetitive, exaggerated, disjointed and seemingly non-purposeful behavior involving two or more animals. However, the category "play" can include a variety of different actions,

including: climb or stand on another, turn circles around another, piggyback ride, peek-a-boo, tickle, arm shake, run away, (one animal runs away from another as an invitation to chase), chest beat, object wave, object shake, object tug/grab, push or nudge, grab/pull, kick, wrestle, play bite, play face. You should try to identify between six and 10 broad behavior categories in your ethogram.

Review your notes from your ad lib narrative and identify the kinds of behaviors you are likely to see. Give your behavior a simple descriptive name and write a one- or two-sentence definition. Be careful: Don't describe a behavior by using the behavior itself. "Walk" can't be defined as "walking fast on four legs." A good example is "grooming": "using the hand to examine and brush through fur." Try to identify behaviors that are mutually exclusive, meaning an animal can only do one of the behaviors at a time. For example, an animal may be sitting and grooming. If you have two behaviors that can be done at the same time, note which behavior is more important (relevant to your research questions) and will have priority in your data collection.

Include behaviors in different categories so that you will be prepared to describe a variety of events that could occur in your group. Just because you saw a 40-minute bout of play during your ad lib observation does not guarantee you will see any play during your scan sample. Be sure to include basic behaviors like eat, walk, sit, and forage (processing food but not actually chewing it).

Worksheet

Write the common and scientific names of the species you have selected, as well as the number and types of individuals. You may need to ask a zoo guide for this information if it is not easily observable or not included on the enclosure placard.

Common Name:	Scientific Name:

	Number of Males	Number of Females
Infants		
Juveniles		
Adults		
Total Count		

1a. Ad Lib Data

Write everything you see happening in the enclosure for a period of 30 minutes. Do not rewrite or type up your notes. Submit the actual notes you wrote at the zoo. Use additional sheets of paper if needed. Write down what happens, who does it, and when.

1b. Ethogram

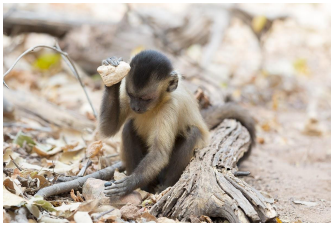
Complete this part of the lab after you finish collecting the ad lib notes.

Name of Behavior	**Code**	**Definition/Description of Behavior**

6.3: Primate Behavior Part II

Primate Behavior Lab: Part II

Format: In person or online



A juvenile capuchin monkey in Serra da Capivara, Brazil, uses a stone as a tool to open a seed.

Author: Rebecca Frank

Source: “Activity 13.” 2019. Frank, Rebecca, Brian Pierson, Philip Stein. LAVC Anthro 111 Lab Manual. 7th Edition.

Time needed: 60-90 minutes

Learning Objectives

- Learn and practice scan sampling
- Learn and practice continuous focal animal follow
- Analyze primate observation data
- Reflect on the process of conducting nonhuman primate observation and data collection

Supplies Needed

- Paper, pencil, clipboard
- Student worksheet
- Stopwatch or cell phone
- Requires zoo visit

Readings

- Jaffe, Karin Enstam. 2019. Chapter 6: Primate Behavior and Ecology. *Explorations*.

Introduction

This lab requires that students visit a local zoo to observe and collect data on nonhuman primates. It is part two of a two-part primate lab. In part one, students learned about basic nonhuman primate behavior, practiced ad lib data collection, and created an ethogram. In part two, students will conduct scan sampling and continuous focal animal follow, analyze their data, and reflect on their findings.

Steps

- In order to complete this lab, students must first complete “Primate Behavior: Part I,” in which students create an ethogram to be used for this lab.
- Students will need to go to the zoo, either in groups or individually, to conduct this lab.
- Students will record their data on the student worksheet (below). The worksheet includes instructions as well as space for data collection and analysis.
- In addition to having students turn in the worksheets, instructors may initiate a class discussion for students to describe their experiences and observations.

Review Questions

- Which behaviors did you see the most? Why do you think they were most common? Which behavior was rare or absent? Why do you think so?
- How might your data be different if you observed for more time or studied a wild group?
- How did male and female individuals behave differently in your data? Or how did older and younger individuals behave differently?

- Explain your observations, discussing specific behaviors.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

Tip: For online courses, students could complete the worksheet and turn it in online. It can also be interesting for students to observe humans with this very different frame. Many zoos have live webcams that would allow students to observe a group of primates from home. See:

- Chattanooga Zoo Tamarins
- Detroit Zoo Japanese Macaques
- Houston Zoo Chimpanzees
- PIN Common Marmosets
- Reid Park Zoo Lemurs
- San Diego Zoo Baboons
- San Diego Zoo Orangutans

References

Frank, Rebecca. 2019. “Activity 13.3: Scan Sampling” and “Activity 13.4: Continuous Focal Animal Follow.” In *LAVC Anthro 111 Lab Manual*, 7th Edition, edited by Frank, Rebecca, Brian Pierson, and Philip Stein.

Jaffe, Karin Enstam. 2019. “Chapter 6: Primate Behavior and Ecology.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attribution

Primate Behavior Part II: Worksheet

Instructions

2a. Scan Sampling

The purpose of this exercise is to discover differences in behaviors and frequency of behaviors among different age/sex categories. You can also use this kind of data to compare different species.

In this exercise you will scan your group every 20 seconds. This means that you will look at what all animals in the enclosure are doing at the same moment by scanning the area from left to right and taking a “mental snapshot” of each individual’s behavior. Mark a “1” in the appropriate behavior row under each animal in the scan sample table: A “1” is marked for each scan for each animal doing that behavior. Do a scan every 20 seconds, at exactly the 20-second mark, and note the behavior you saw each individual engaging in. Then stop until the next 20-second mark. Any behavior that occurs before or after the 20-second mark is ignored.

You score one behavior for each animal during each scan. If a particular animal cannot be seen, you still need to account for it. Include the behavior “out of sight” on your scan sample table, where you can mark this type of occurrence. If during a scan a particular animal is engaged in more than one behavior, note the priority behavior, as you determined in the ethogram section. With our limited ethogram, it is likely an animal will do something that does not fit any of your listed behaviors. In such instances, include the behavior “other” on your scan sample table.

The point of a scan sample is to gain a general sense of how a group spends its time. It usually focuses on a limited number of behaviors and, as you will see, it fails to record a great deal of what actually occurs. Think about the types of behaviors best captured via this method and the types of behaviors that should not be studied using a scan sample.

Below is a small example of a scan sample with only 10 scans. The behavior observed for each animal during a scan has been marked by a “1.” Each column adds up to 10.

Behavior	Adult Male	Adult Female 1	Adult Female 2	Juvenile Male
Walk	11	1	11	11

Feed	1111	1111	11111	111
Auto-groom	11	111	111	
Solitary play	11	11		11111
Total	10	10	10	10

Each behavior for each animal can then be calculated: # of observed scans/ # of total scans*100. This will tell you the percent of scans spent doing each behavior. In the first box, 2 marks = 2/10 scans*100 = 20%. The adult male spent 20% of his observation time walking. This can be compared to the Adult Female 1 who has 1 mark in that first row = 1/10 scans*100 = 10% of her observation time spent walking.

2b. Continuous Focal Animal Follow

In the scan sample data, you recorded a series of “snapshots” of activity across a whole group. This can generate a lot of data about many individuals. However, it also fails to record a great deal of detail about the sequence of behaviors leading up to, and following from, a single event that you record in your scan.

Continuous focal animal follows represent the other end of the data collection spectrum. In this method you continuously monitor the activities and interactions of a single animal—your focal animal—for a set period of time. At the end of that time period you begin a new sample on a different focal animal. By continuously following the activities of one individual, you record much more detail than in a scan sample, but you only have details about one individual and those it interacts with. It also takes a lot more time to gather enough data because you are watching only one animal at a time. See the example below.

Focal: Adult Female 1

Time	Behavior
3:30:00	AF1 walk (abbreviated wlk)
3:3014	AF1 approach (app) AF2, AF1 lunge (lun) AF2
3:30:20	AF2 leave (lv) AF1
3:30:43	AF1 sit eat
3:34:02	AM app AF1, AF1 stop eat sit
3:34:10	AF1 groom (grm) AM
3:42:27	AF1 stop groom (stgr) AM, AF1 lean (ln) AM
3:42:35	AM lv AF1, AF1 eat

In this example, only a limited number of behaviors are recorded. And while you can use these codes to re-create what happened, it doesn’t read like a running narrative of *everything* that happened. Also note that some behaviors, like groom, have a clear start and stop time. Other behaviors, like lunge, just happen and do not last a period of time. Finally note that the adult female is the focus, though you do capture her brief interaction with another female and an adult male.

Continuous focal data can be more difficult to analyze than scan sample data. In this exercise we will look at the duration of a behavior, such as grooming or eating.

Remember in the scan sample, you counted instances of a behavior, and then calculated a rate based on how many scans (or instances) that behavior occurred out of your total number of scan observations. With continuous data, you know exactly when a behavior began and when it ended, so you can figure out exactly how many seconds an individual spent grooming or eating (for example). The number of seconds spent doing a behavior divided by the total number of seconds spent observing an individual will also give you the rate or proportion of time spent in that activity. Rates from scan samples and continuous follows are usually very similar, assuming enough data has been collected over multiple days and during similar times of day.

Worksheet

2a. Scan Sampling

In the table on the following page, list the behaviors from your ethogram down the rows in the left column. Across the top, list the animals in your study group.

Do 50 scans. Noting the behavior for each individual every 20 seconds by making a 1 (tick mark) in the correct box. This will take you about 17 minutes to do 50 scans, one scan every 20 seconds. Use your phone or a stopwatch to keep track.

Behaviors ⇓	IDs ⇒				
Not Visible					
Other					
Total Scans	50	50	50	50	50

From your scan sample data, sum the marks in each box (total number of observations for each behavior for each individual). Divide each sum by 50 (total number of scans) and multiply by 100. Write this percentage in the cells of the scan sample data using a different color pen or pencil so you can easily read them.

For example, if you observed 15 instances of allogrooming in the adult female, then 15 observed instances divided by 50 scans, times 100 is 30%. Do this for each box in the chart, and record the rates (percent of observation time). Each column should add up to 100 percent.

2b. Continuous Focal Animal Follow

For this exercise, use your same set of ethogram behaviors (from “Primate Behavior Lab: Part I”) and select one of the individuals in the same primate group you have been watching to be your focal animal. In the empty space on the following page, record the ID of that individual, the time you will begin watching, and then on each line, record the time to the nearest second (as best you can) for everything that individual does, recording *only* behaviors listed in your ethogram. Start a new line as the time or the activity changes. Continuously record everything your focal does for 10 minutes. In some ways, this will look like the ad lib data, except that it will only use your ethogram behaviors and will focus on the activity of a single animal. This type of data is often recorded using abbreviated codes for the behaviors to make recording data faster, so use the codes from your ethogram. It is also common to record the details of interactions between your focal and another individual.

Focal ID:

Start Time:

Tallying the Focal Data

Select one behavior from your ethogram that you observed during both your scan sample and your continuous focal follow. Select a behavior that has a start and stop time and lasts for a duration (such as eating, sitting, grooming, or play). In the following table, calculate how many seconds your focal animal spent performing that behavior and then calculate the rate by dividing by 600 seconds (the number of seconds in 10 minutes).

Behavior:

Start Time	Stop Time	Duration in Seconds

Total Duration of Behavior:

Rate = Total Duration of Behavior/600 seconds =

How much of the time did your focal spend doing this behavior during the focal sample? During the scan sample? Are these rates similar? Why do you think the rates were or were not similar?
Did you prefer scan sample or focal follow data? Why?

When you have completed your calculations, answer the following questions, discussing your results. You may do this at the zoo or another time before the exercise is due.

What behaviors did you see the most? Why do you think those were the most common? What behavior was rare or absent? How might your data be different if you observed for longer or if you studied a wild group?

How did male and female individuals behave differently in your data? Or compare older and younger individuals. Explain your observations, discussing specific behaviors you observed.

CHAPTER OVERVIEW

7: Understanding the Fossil Context

Learning Objectives

- Demonstrate an understanding of stratigraphic dating
- Construct a Harris Matrix
- Apply the concepts of *terminus ante quem* and *terminus post quem*

Thumbnail: Image Caption: Harris Matrix

7.1: Stratigraphic Dating and the Harris Matrix

Stratigraphic Dating and the Harris Matrix

Format: In person or online

Author: Jess Whalen

Source: Activity 8.1. Paskey and Beasley Cisneros (editors). *Digging into Archaeology*.

Time needed: 45 minutes

Supplies Needed

- Photographs (attached)
- Student worksheet (attached)

Readings

- King and Zajicek. 2019. Chapter 7: Understanding the Fossil Context. *Explorations*.
- Paskey and Beasley Cisneros. 2020. Chapter 8: Dating Methods—Relative and Absolute Dating. *Digging into Archaeology*.

Introduction

This activity consists of three parts. Each part includes a description of a dating technique, a situation, and a series of questions for students to answer on the worksheet (below).

Part 1 focuses on stratigraphic dating, a relative dating method that establishes if something is older or younger than something else. Using this method, students assess several images. Part 2 introduces the Harris Matrix, which is used to diagram materials based on their relative ages. Given a specific scenario, students are asked to construct a Harris Matrix and answer questions about it. Part 3 describes the concepts of *terminus ante quem* (the "date before which" or DBW) and *terminus post quem* (the "date after which" or DAW). Students then apply these concepts to a real-world situation.

Steps

1. Students can complete this activity individually or in small groups.
2. This is a three-part activity. Before each part, the instructor or a student should read aloud, to the class, the information about it (which is included on the worksheet below).
3. Part 1. Students are shown photos (attached below) that depict a collection of items on a table: a cup, saucer, newspaper, and tickets. Instructors may choose to display these photos on slides or hand them out to students. The students are asked to imagine the items as part of a single context, such as a layer in an excavation. The students must determine whether the items were deposited all at once in a single event or one after the other over time.
4. Part 2. The instructor explains the Harris Matrix to students and asks students to construct a Harris Matrix based on the information from Part 1 and answer questions.
5. Part 3. Based on the concepts of *terminus ante quem* and *terminus post quem*, students answer the questions on the worksheet.
6. Students share their results with the class.

Conclusion or Review Questions

By completing this activity, students will achieve a better understanding of relative dating techniques, particularly stratigraphic dating, the Harris Matrix, and concepts of *terminus ante quem* and *terminus post quem*. Students will learn the value of these techniques for determining which objects or events are younger or older than others in a particular context.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be according to this scale (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

If applicable, include tips and suggestions on how to adapt this lab for online learning.

Reference

Whalen, Jess. 2020. “Stratigraphic Dating and the Harris Matrix.” In Amanda Wolcott Paskey and AnneMarie Beasley Cisneros, *Digging into Archaeology: A Brief OER Introduction to Archaeology with Activities*. CC BY-NC. https://asccc-oeri.org/wp-content/uploads/2020/06/OERI-Archaeology_Final_4_29.pdf

Stratigraphic Dating Worksheet

Part 1. Stratigraphic Dating: A Café Scene

Relative dating methods establish the date of something as older or younger than something else rather than anchoring its age to an absolute, scaled timeline, as in absolute dating. So, we determine the sequence of at least two things (two events, two deposits, etc.) and establish what happened first, what happened next, and so on.

In archaeology, relative dating relies on stratigraphy—what material is located above or below something else. The Law of Superposition tells us that material positioned underneath something else is usually older and material overlying a deposit is younger than the deposit, unless the layers have been disturbed.

The photos that you will be shown depict a collection of items on a table: a cup, saucer, newspaper, and tickets. Imagine that these items are part of a single context such as a layer in an excavation and you want to determine whether they were deposited all at once as a single event or one after the other over a longer period. Examine the photos and answer the following questions.

1. Using the Law of Superposition, which material is the oldest?

2. Which is the youngest?

3. How do you know this?

Part 2. The Harris Matrix

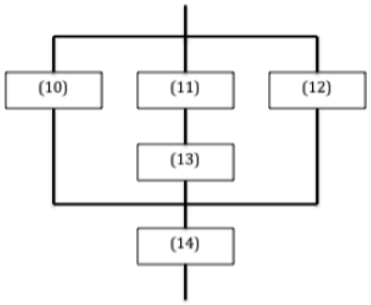
To map the succession of layers in a context (site), archaeologists use a Harris Matrix. It allows us to draw a diagram of the materials above and below other materials so we can understand the succession of deposits and determine the site’s approximate date.

The Harris Matrix uses boxes and lines to clarify the stratigraphic relationship of the objects. Each item is represented by an individual box, and the boxes are drawn alongside, above, and below each other and connected by straight and parallel lines to show the stratigraphic relationships and, thus, their relative positions.

These rules are important when drawing a Harris Matrix:

1. Draw the boxes representing all of the materials from a single layer *along a horizontal plane* (in the same horizontal layer). Each horizontal plane/layer must be clearly distinguishable from the layers above and below it.
2. Draw only straight vertical and horizontal lines—no curving lines.
3. Connect the boxes representing materials that are directly associated—are touching each other—with *horizontal lines*. Do not connect boxes representing materials in the same horizontal plane that are not touching other materials with horizontal lines.
4. Connect a box to boxes directly above and below it with vertical lines. Also use vertical lines to connect boxes representing a displaced (pushed aside) item and the box representing the item that disturbed it.

The following Harris Matrix shows boxes for five items listed as 10, 11, 12, 13, and 14. From the matrix, we can see that items 10, 11, and 12 were found in a single horizontal layer and that item 11 was touching items 10 and 12. Item 11 was found directly above item 13, and item 13 was found directly above item 14.



Use this Harris Matrix to answer the following questions.

1. Which item is the oldest material in this context? Which is the youngest?

2. Draw a Harris Matrix representing the collection of items in the café photographs. Use boxes to represent the items (cup, saucer, tickets, newspaper) and place the boxes alongside, above, or below each other based on their positions in the photograph. Connect items that are directly associated (touching) with straight vertical and horizontal lines. Be prepared to share your matrix and answers with the class.

Part 3. Date Before Which and Date After Which

Even when using relative dating methods, we are interested in establishing at least approximate dates for our deposit. We do this by establishing the *terminus ante quem* (the "date before which" or DBW) and *terminus post quem* (the "date after which" or DAW) for deposit at the site.

***Terminus Post Quem*—Date After Which**
The DAW is the *earliest* possible date for the materials. They ***cannot*** have been deposited *before* this date. The DAW is found by determining the latest possible use of the materials.

Consider a shaving kit found in a garbage pit that contains a razor, scissors, and tweezers. You determine that the razor was manufactured from 2009 through 2012 while the scissors and tweezers were manufactured only in 2015. Thus, the earliest possible date of deposit for this collection is 2015 since some of the materials did not exist prior to that year.

***Terminus Ante Quem*—Date Before Which**
The DBW is the *latest* possible date for the materials. They ***cannot*** have been deposited *after* this date. In this case, dates of manufacture do not work since many utilitarian objects such as the razor and scissors in our example are used for many years and even across generations. Instead, we establish the date of the earliest known event that occurred after the materials were deposited.

Returning to our shaving kit, we know it was deposited no earlier than 2015 (the date of manufacture of the tweezers and scissors), but we do not know when the kit was thrown into the garbage pit. The first event we know of after 2014 is a volcanic eruption that covered the pit area with ash in August 2017. Therefore, we know that the latest possible date for the deposit of the shaving kit is August 2017.

1. Fill in the blanks in the following passage.
   In a single site context, we have two coins found inside a pair of jeans. One coin is dated to November 1998 and the other is dated to June 1992. The jeans were manufactured between July 2001 and June 2005. Therefore, the *earliest* possible date for this context is _____. The material cannot have been deposited earlier than _____. This is the date _____ which is also called the *terminus* _____ *quem*.
2. Is it possible for a pair of jeans to be worn after the last date of their manufacture?
3. How can you establish a *terminus ante quem* for the jeans using information about the coins inside? Use your imagination!
4. Determine the earliest possible date for the café scene in the photographs by examining the photographs for dates on items, such as the tickets and newspaper.

On the Harris Matrix you previously made for the café items, insert the dates you find for each ticket and the newspaper.

5. What is the *terminus post quem* for the café scene? How do you know?

6. A *terminus post quem* is also called the "_____." It is the _____ possible date for a context.

7. How could you establish a *terminus ante quem* for the café scene? Be prepared to share your ideas with the class.

8. How long is the period during which you think the café items were deposited? Why?

9. What do you think happened at the café site and why? Reconstruct the sequence of activities.

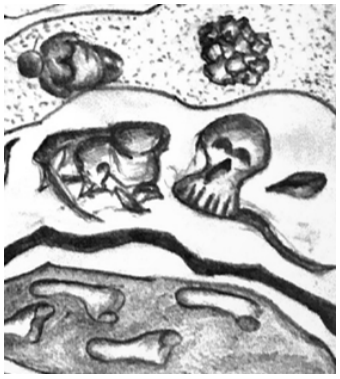
Additional Documents: Photos


York Times
National Edition
FRIDAY
25
JULY 14
NOT FOR SALE
KEEP
WEDNESDAY
23
JULY 14
NOT FOR SALE

7.2: Dating Exercise

Dating Exercise

Format: In person or online



One section of the fictional site stratigraphy that students will date. Art by Alexandra Broehl

Author: Kristen A. Broehl and Stephanie J. Cole

Time needed: 90-120 minutes

Learning Objectives

- Differentiate between chronometric and relative dating methods
- Recognize scenarios when different dating methods are useful, including materials and date ranges appropriate for chronometric techniques
- Analyze a stratigraphic profile by combining chronometric and relative methods

Supplies Needed

- Note cards (in person)
- Student worksheet
- Descriptions of Strata document

Readings

- King, Sarah S. and Lee Anne Zajicek. 2019. Chapter 7: Understanding the Fossil Context. *Explorations*.

Introduction

To complete this activity, students will use a stratigraphic profile and supplementary descriptions to estimate the dates for each stratum at the site and the assemblages within them. The goal of the activity is to help students recognize which methods are most appropriate for dating different strata. When a layer requires chronometric dating, students submit a request to a "lab" (i.e., the instructor) and must use the data they receive along with cultural or biostratigraphic information to produce the most precise dates possible.

Steps

1. Make photocopies of the note cards document provided in the Additional Documents section. Make sure to copy enough note cards, so that each group can receive results from each test. Also be sure to copy extra *error* note cards, so there are enough to return to students if they request tests that are not appropriate (e.g., requesting radiocarbon dating on rock or for materials older than 50,000 years). Cut out the note cards and keep them in separate stacks for easy distribution.
2. Create groups comprising approximately three to five students. Provide each student with the student worksheet and each group with at least one copy of the Descriptions of Strata document.
3. Ask each group to review the stratigraphic profile and descriptions to identify materials within each layer that they can date with relative or chronometric (radiocarbon, potassium-argon, or argon-argon) techniques. Students should use this information to complete the student worksheet.

4. For materials that the students want to date chronometrically, they must submit a written request to the "lab" (i.e., the instructor) that includes the material to be dated (e.g., bone, volcanic rock, etc.), the letter of the layer the material comes from, and the chronometric method they want to use. As groups submit chronometric dating requests to the "lab," the instructor gives them the appropriate note card with the results of their request. If you return an *error* result, ask a question that will prompt the group to think about why their request is problematic (see Tips and Suggestions below).
5. Review the dates of each layer as a class, discuss challenges, and address questions.

Review Questions

Using examples from the activity, what are the pros and cons of chronometric dating? What are the pros and cons of relative dating?

What are some limitations associated with radiocarbon and potassium-argon (or argon-argon) dating?

What obstacles did you face while trying to date the assemblages at this site?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it is (mark in bold):

This lab exercise is easily adaptable to online course formats. In synchronous classes, students can work independently or in Zoom breakout groups to complete the activity. When students are ready to submit a sample for dating to the lab (i.e., the instructor), they can message the instructor individually with their request (via email, private Zoom chat, etc.), and the instructor can message back with the results.

For asynchronous course formats, instructors can provide students with the chronometric dating results along with the strata descriptions. In this case, the activity is focused more on accurately combining the relative and chronometric data to estimate the dates of each stratum rather than recognizing when to use chronometric versus relative techniques.

Alternatively, instructors could provide students with the stratigraphic profile image and strata descriptions and ask them to write a short "proposal" to the site's director requesting funds for chronometric dating. The proposal should describe (1) the current estimated dates of each layer, including details about how they found the date ranges for each layer, and (2) the chronometric dating tests for which they need funding, including the material(s) within the specific layers they want to date, which chronometric methods they would use for each material and why, and how the chronometric results could improve the dating of relevant layers.

Tips and Suggestions

Be sure to remind students what +/- means in a date (e.g., 5,000 +/- 500 years ago) since many students are not familiar with this notation. See the Additional Documents section below for the thought process behind the dates of each layer and sample questions to prompt students that are struggling with dating certain strata. The note cards needed for in person instruction can be found here as well.

Image Attribution

The image of the stratigraphic profile was drawn by Alexandra Broehl.

Additional Documents

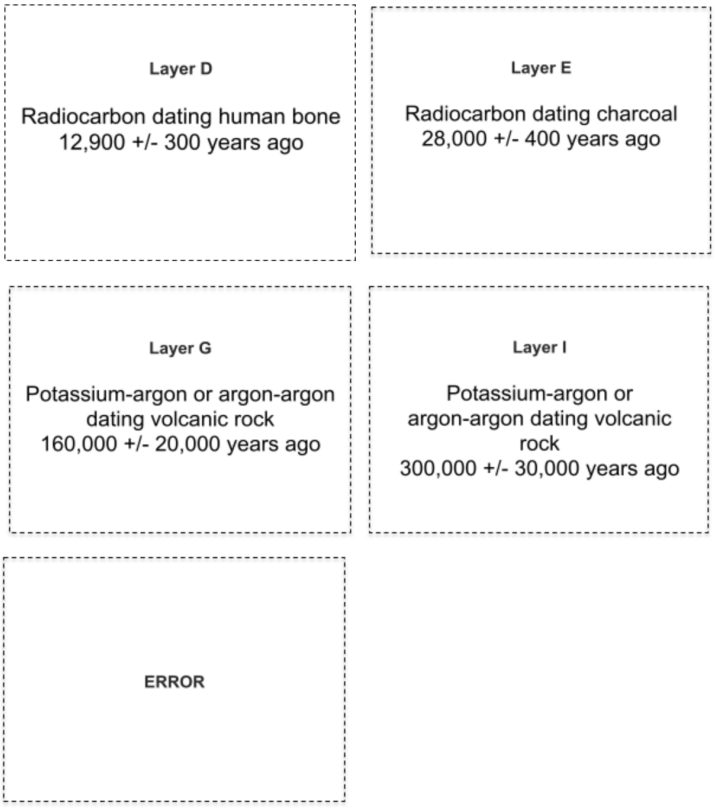
Below is the thought process behind the dates for each layer and sample questions to prompt students who are struggling:

1. Present layer.
2. The earliest date for the deposit is 1905 since that's the earliest time a machine-made bottle would have been produced. The end date is unknown; even though the company shut down in 1920, the bottle could have been deposited long after it was initially purchased.
3. The dates of the coins show that the layer is only a few hundred years old, so the deposit is too young to radiocarbon date the bone. The coins are associated with the skeleton and therefore represent a single deposition event. Therefore, the coins provide the earliest year for the deposit (1736), based on the date of the most recent coin. The coins were out of use after 1750, so they were likely deposited before that date.
   a. If students request a radiocarbon date for the skeleton, the instructor can ask: "What is the date range for when radiocarbon can be used? Is the skeleton at least 500 years old?"

b. If students put 1727 as the early date (the earliest coin date), ask: “In the year 2020, can you have a penny from 2010? Can you have a penny from 2030? So, could the coins have been deposited before 1736?”

4. Based on the harpoons, the skeleton is relatively dated to the Magdalenian, which indicates that the skeleton is within the proper date range for radiocarbon dating. Radiocarbon dating the skeleton yields a result of 12,900 +/- 300 years ago (12,600–13,200 years ago).
5. The relative dates of the Venus figurines show that the layer is within the range for radiocarbon dating and charcoal is available. Radiocarbon dating the charcoal gives a result of 28,000 +/- 400 years (27,600–28,400 years ago).
6. The dates of the Mousterian tools provide an approximate range for this layer of 40,000–150,000 years. The woolly rhinoceros and saber-toothed cats are not helpful in decreasing the range because they lived throughout that time frame. However, the presence of the straight-tusked elephant shows the layer is older than 50,000 years ago. Initially, the dates cannot be further narrowed, but dating the next layer leads to an upper estimate of 140,000 years ago.
   a. If students request radiocarbon dates of the fossils, the instructor can ask: “What is the date range when radiocarbon dating can be used? Is this layer less than 50,000 years old?”
7. This layer is made of volcanic rock and the dates of the previous layer show it is likely older than 100,000 years, so it can be dated chronometrically with potassium-argon or argon-argon methods. The test returns dates of 160,000 +/- 20,000 years ago (140,000–180,000 years ago).
   b. If students indicate they don’t know how to date this layer, the instructor can ask questions such as: “What material makes up Layer G? Do we have any methods to date volcanic rock?”
8. Initially, only the more recent date can be estimated based on the upper limit of Layer G (180,000 years ago). After dating Layer I, students will have the other date for this layer (270,000 years ago).
9. Layer I is made of volcanic rock, so it can be dated chronometrically with potassium-argon or argon-argon methods. The test returns dates of 300,000 +/- 30,000 years ago (270,000–330,000 years ago).
10. All that can be said about this layer is that it is older than Layer I, so estimated 330,000+ years ago.

Note cards with chronometric dating results:



Dating Exercise: Student Worksheet

You are an anthropologist who recently participated in an excavation at a site in Europe. Before your team can publish an article about your site, you need to determine the ages of the various strata and artifacts that your crew found.

A drawing of the site's stratigraphic profile is included below, and information concerning the archaeological and paleontological specimens removed from each layer is available in the Descriptions of Strata document. Using this information, you will calculate the approximate date ranges for several specimens. You can use a mixture of chronometric and relative dating methods to accomplish this task. When using chronometric methods, you will send a sample off to a lab (i.e., the instructor) which will provide you with the results of the analysis. The lab can handle radiocarbon, potassium-argon, and argon-argon requests. When making your request, please submit in writing the specific method you would like to use for analysis (for example, radiocarbon dating), the object you would like dated, and the object's position within the stratigraphic profile (i.e., the layer letter).

First, write the date range you obtain for each layer next to the stratigraphy below. Then, based on your stratigraphic analysis, please answer the questions on the next page.

Dates:

A. _____

B. _____

C. _____

D. _____

E. _____

F. _____

G. _____

H. _____

I. _____

J. _____

Drawing by Alexandra Broehl

Questions:

1. When were the fossilized footprints from Layer I made, and how do you know?

2. Approximately when were the skeletal remains in Layer C deposited? Briefly describe the process you used for dating the remains.

3. How old are the skeletal remains in Layer D? How do you know?

4. Approximately when did Neanderthals occupy this site? How did you reach this conclusion?

5. Approximately how many years ago were the Venus figurines from the site used? Briefly describe the process you used for dating them.

6. What is the date range for Layer H? How do you know?

7. What is the date range for Layer J? How do you know?

Descriptions of Strata

Layer A

This is the current surface, as well as the immediate subsurface, of the site.

Layer B

Fragments of historic glass and ceramics were found in this layer, but most were not sufficiently intact to contain diagnostic information. One intact glass bottle (a) was removed from Layer B. Characteristics of the bottle's seams show that it was machine-

made. Automated bottle-making machines were first used in the region around 1905. The bottle has a manufacturer's mark from a company that shut down in 1920.

Layer C
Layer C yielded one human burial in an extended position (b). A cache of coins inside a jar (c) was associated with the skeleton. Several coins were too worn to discern any pictures or writing, but coins that were readable had the years 1727, 1733, 1734, and 1736. These types of coins were no longer used after 1750.

Layer D
This layer contained one human skeleton in a flexed position (d). Two bone harpoons (e, f) were in the grave, which were stylistically consistent with artifacts from nearby sites dated to the Magdalenian (ca. 17,000–11,000 years ago).

Layer E
Layer E included charcoal from a hearth that was likely used for cooking (g). This stratum also contained two clay Venus figurines (h, i). Venus figurines are usually dated around 21,000 to 26,000 years ago but can be found between 35,000 to 11,000 years ago.

Layer F
From Layer F, excavators removed several stone tools. Two of the tools (j, k) were diagnostic of the Mousterian industry, which is a technology used by Neanderthals between approximately 150,000 to 40,000 years ago. The fossilized remains of three extinct species were also found in Layer F. One species was a woolly rhinoceros (l), which is estimated to have existed from about 3 million years ago to 10,000 years ago. Another species was a straight-tusked elephant (m), which lived in the area approximately 400,000 to 50,000 years ago. The third species was a saber-toothed cat (n), estimated to exist 42 million years ago to 11,000 years ago.

Layer G
This stratum was made of volcanic rock and contained no cultural or paleontological material.

Layer H
The only significant find in Layer H was the fossilized cranium of an unidentified hominin (o).

Layer I
Layer I was made of volcanic rock and contained the preserved footprints of a bipedal hominin.

Layer J
This was the deepest stratum and contained the fossilized cranium (p) and femur (q) of an unidentified hominin(s). Charcoal (r) was present, but it is unknown whether the fire was intentional.

7.3: Reconstructing Paleo-environments

Reconstructing Paleo-environments

Format: In person or online

Dicrostonyx torquatus, a Euroasian species of rodent.

Author: Gillian Wong

Source: Activity 10.1. Amanda Paskey and AnneMarie Beasley Cisneros. 2020. *Digging into Archaeology*. CC BY-NC. https://asccc-oeri.org/wp-content/up...Final_4_29.pdf

Time needed: 60 minutes

Learning Objectives

- Detect the Pleistocene-Holocene boundary
- Familiarize yourself with archaeological research questions that can be answered using microfaunal remains

Supplies Needed

- Microfauna descriptions and data set (attached)
- Paper and pen/pencil

Readings

- King, Sarah and Lee Anne Zajicek. 2019. Chapter 7: Understanding the Fossil Context. *Explorations*. CC BY-NC.
- Paskey, Amanda W. and Cisneros, AnneMarie B. 2020. Chapter 10: Reconstructing Environments and Subsistence Patterns, pages 123–127. In *Digging into Archaeology*. CC BY-NC.

Introduction

Hi, I'm Gillian Wong, a zooarchaeologist who specializes in using microfauna—small animals like rodents, insectivores, bats, reptiles, and amphibians—to reconstruct past environments. I use these reconstructions to address questions about hunter-gatherer landscape use and adaptation. This exercise uses a fictional data set but is based on work I did for my Ph.D. at a site in southwestern Germany.

Our first year of excavation at the site was a year of test excavations, meaning we were testing the location for intact archaeological deposits. As the faunal analyst for the site, I first addressed the task of determining whether the site was from the Holocene (11,700 years ago to the present), the Pleistocene (2,580,000 to 11,700 years ago), or both. This temporal distinction allowed us to predict what cultural remains would likely be present. Fortunately, we can use the rodent and insectivore remains from a site to make this determination, which tends to be much faster than using 14C dating.

Rodent and insectivore (insect-eating) remains are deposited in archaeological sites as a result of predation by raptors and small carnivores; they almost never end up at sites in large numbers as a result of human activity. Many rodents and insectivores live only in specific environments, and the latest Pleistocene and Holocene environments in Central Europe were very different. During the latest part of the Pleistocene, the environment in Central Europe was primarily cold, dry tundra and steppes (forestless grasslands). During the Holocene, the environment was warmer and was forested.

About the data:

The data set and excavation methods presented in this activity are based on work conducted for my Ph.D. and excavation methods used by the University of Tübingen.

The data set describes remains found at Paleolithic rock shelter sites in southern Germany. The fictional site has five archaeological horizons (strata), numbered from the top layer and proceeding downward as 1, 2, 2a, 3, and 4.

The fictional site was excavated in quadrants that were 1 meter by 1 meter in dimension. Each quadrant has its own "find numbers," meaning that more than one quadrant can produce the same find number. Therefore, each artifact is identified by the designation of the quadrant (A, B, C, etc.) and the find number—A112, for example, signifies that the artifact was the 112th find from quadrant A.

Microfaunal remains, usually bones and teeth, were recovered during screening because of their small size. In the following database, all of the microfaunal remains came from water-screened sediment so the Artifact Type for those lines is "Sediment Bucket." All of the macrofaunal specimens yielded by a bucket of sediment (from several to hundreds) were assigned a single find number.

Most of the recorded data describe teeth. You'll notice, for example, many references to "lower M1" in the Element column. This means that the specimen recorded is a lower first molar. You'll also see "lower P4," which refers to lower fourth premolars. "C" stands for canine and "I" stands for incisor.

Steps

- This activity could be done individually or in groups. Depending on time and class size, the instructor may choose to divide the class into five or more groups, assigning one or more of the five archaeological horizons (1, 2a, 2b, 3, and 4) to each group.
- Review the microfauna database (attached below).
- Use the database and information about rodent and insectivore environmental preferences to determine whether there is evidence for a stratigraphic differentiation between the cold, open Pleistocene and the warm, forested Holocene at the site.
- Present your results:
  - Make a figure showing the presence or absence of cold-adapted and warm-adapted microfauna for each archaeological horizon.
  - Make a table quantifying the number of specimens belonging to each taxon (genus and species) for the five archaeological horizons.
  - Write a report that includes: i. whether you could find a Pleistocene-Holocene transition at the site and, if so, its stratigraphic location. ii. The data you used to draw your conclusions. iii. Any uncertainties presented by the data.

Conclusion

This activity will give students an appreciation for the archaeological significance of microfauna and what it reveals about specific environment conditions. In this example, students will learn to analyze microfaunal evidence in order to determine the Pleistocene-Holocene boundary, a time period marked by several changes in human behavior, such as the development of the bow and arrow, more sedentary lifestyles, and the eventual development of farming. Throughout this exercise, students will acquire the ability to examine and synthesize a large data set.

Adapting for Online Learning

Rank how adaptable to online learning this lab/activity is:

If applicable, include tips and suggestions on how to adapt this lab for online learning.

Tips and Suggestions

- When working with big data sets like this one, I find it easiest to play around with the data first. I read through it a few times. I look for things that I do and don't understand. If I have the data on a computer, I like to reorganize it a few times. For example, I might start by sorting it by archaeological horizon, then I might sort it by different species of microfauna.
- When I sort the data, I look for any patterns or anomalies that stick out to me. This can help me feel more comfortable before I really dive in.
- When reading the "About the data" section, try to imagine the site and the way things are organized. Sketch a picture or take some notes for yourself that you can refer to later if the database starts to feel confusing. I like to draw a picture of the stratigraphy (called "archaeological horizons" in this data set) before I get started so I can remember which layers are on top and which are on the bottom.
- In archaeology, we almost never know the answer completely, so it's normal to have some finds not fall within your predictions. Discuss the broad, overall picture, then address any finds that don't agree with this picture and what might have caused this.
- Consider the behaviors of these microfaunal species when they were alive. Do they live in groups? Do they live underground? What do they eat? How are they hunted? Who hunts them? Think about how this can inform your conclusions or lead you to

further research questions.

For Further Exploration

Habitat preferences of microfauna species:

The IUCN Red List of Threatened Species: https://www.iucnredlist.org

Animal Diversity Web:

https://animaldiversity.org/

Using animal remains to reconstruct past environments:

Lyman, R. L. 2017. Paleoenvironmental Reconstruction from Faunal Remains: Ecological Basics and Analytical Assumptions. Journal of Archaeological Research 25: 315-371.

Andrews, P. 1995. Mammals as palaeoecological indicators. Acta Zoologica Cracoviensia 38(1): 59–72. http://www.isez.pan.krakow.pl/en/acta-zoologica.html.

Faith, J. T. and Lyman, R. L. 2019. Paleozoology and Paleoenvironments: Fundamentals, Assumptions, Techniques. Cambridge University Press, Cambridge.

References

Mathias et al. 2017. Microtus agrestis (Rodentia: Cricetidae). Mammalian species 49(944): 23-39.

Niethammer, J. and Krapp, F. 1982. Handbuch der Säugetiere Europas. Band 2/I Nagetiere II.

Akademische Verlagsgesellschaft Wiesbaden.

The IUCN Red List of Threatened Species: https://www.iucnredlist.org.

Walker, Ernest P. 1968. Mammals of the World. Second Edition. Volume II. The Johns Hopkins Press, Baltimore.

Image Attribution

https://commons.wikimedia.org/wiki/F..._torquatus.png

Paleoenvironments: Worksheet

After examining the microfauna descriptions and analyzing the data set(s):

a. Make a figure showing the presence or absence of cold-adapted and warm-

adapted microfauna for each archaeological horizon.

Archaeological horizon	Cold-adapted microfauna? (X = present)	Warm-adapted microfauna? (X=present)
1		
2a		
2b		
3		
4		

b. Make a table quantifying the number of specimens belonging to each taxon

(genus and species) for the five archaeological horizons.

Taxon	# in horizon 1	# in horizon 2a	# in horizon 2b	# in horizon 3	# in horizon 4

c. Write a report that includes: i. whether you could find a Pleistocene-Holocene transition at the site and, if so, its stratigraphic location. ii. The data you used to draw your conclusions. iii. Any uncertainties presented by the data.

Paleoenvironments: Data Set

Environmental Preferences of Microfauna*

Common Name	Species Name	Environmental Preference	Comments
Common Shrew	*Sorex araneus*	Prefers habitats that have dense vegetation and are damp, such as riparian forests and reed beds Does not live in very dry (arid) habitats	Insectivore; from the subfamily *Soricinae* (red-toothed shrews)
Eurasian Water Shrew	*Neomys fodiens*	Prefers to live near streams, lakes, and marshes	Insectivore; from the subfamily *Soricinae* (red-toothed shrews)
Common Mole	*Talpa europaea*	No specific preference except for ground that is diggable (not frozen or close to bedrock), because they live almost their entire lives underground	Insectivore; identifiable by its teeth, cranium, and forelimb long bones (such as the humerus)
Edible Dormouse	*Glis glis*	Prefers to live in woodlands, especially deciduous woodlands	Rodent
Yellow-Necked Mouse	*Apodemus flavicollis*	Prefers to live in woodlands, especially deciduous woodlands	Rodent
Red-backed Vole	*Myodes glareolus*	Prefers forested areas or densely covered clearings on the margins of forests	Rodent
Water Vole	*Arvicola Terrestris*	Prefers to live near bodies of water (rivers, streams, marshes, lakes) in both lowlands and on mountains	Rodent
Common Vole	*Microtus arvalis*	Lives in a wide variety of open habitats but has no particular preference	Rodent; only identifiable by its lower first molar. Often grouped with *M. agrestis*
Field Vole	*Microtus agrestis*	Prefers areas with dense vegetative cover and areas that are wet	Rodent; only identifiable by its lower first molar and upper second molar. Often grouped with *M. arvalis*
Narrow-headed Vole	*Microtus gregalis*	Prefers tundra and steppe environments that are open and cold In forests and semi-deserts, it lives in grassy areas	Rodent; only identifiable by its lower first molar
Eurasian Snow Vole	*Chionomys nivalis*	Prefers mountainous areas above the tree line where it is rocky, open, and cooler	Rodent; only identifiable by its lower first molar or baculum (penis bone)
Collared Lemming	*Dicrostonyx torquatus*	Prefers cold tundraenvironments	Rodent

Data Set

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	7	1	12	*Microtus arvalis/agrestis*	lower M1 (molar 1)	L	complete	oxide staining
A	7	1	4	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	7	1	1	*Glis glis*	upper M3 (molar 3)	R	complete	oxide staining
A	7	1	1	*Sorex araneus*	lower P4 (premolar 4)	L	complete	
A	7	1	2	*Myodes glareolus*	lower M2 (molar 2)	R	complete	
A	15	1	2	*Microtus arvalis/ agrestis*	lower M1	L	anterior (back) half	oxide staining
A	15	1	5	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	15	1	1	*Apodemus flavicollis*	lower M1	R	complete	articulates with mandible and lower M2 and M3
A	15	1	1	*Apodemus flavicollis*	lower M2	R	complete	articulates with mandible and lower M1 and M3
A	15	1	1	*Apodemus flavicollis*	lower M3	R	complete	articulates with mandible and lower M1 and M2
A	15	1	1	*Apodemus flavicollis*	Mandible (lower jaw)	R	horizontal ramus (back part of jaw)	articulates with lower M1,M2, and M3
A	21	1	2	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	33	1	4	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	33	1	6	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	33	1	3	*Myodes glareolus*	lower M1	L	complete	oxide staining
A	33	1	1	*Talpa europea*	humerus (upper arm bone)	R	nearly complete	
A	35	1	7	*Microtus arvalis/agrestis*	lower M1	L	complete	oxide staining
A	35	1	5	*Microtus arvalis/agrestis*	lower M1	R	complete	oxide staining

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	35	1	1	*Arvicola terrestris*	upper M2	R	complete	oxide staining
A	35	1	1	*Arvicola terrestris*	upper M1	R	complete	

A	35	1	1	*Myodes glareolus*	lower M1	L	complete	
A	51	2	1	*Sorex araneus*	mandible	L	complete	oxide staining
A	51	2	1	*Sorex araneus*	lower P4	L	proximal (upper) horizontal ramus	
A	51	2	10	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	51	2	3	*Myodes glareolus*	upper M3	R	complete	oxide staining
A	51	2	12	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	52	2	3	*Myodes glareolus*	lower M1	L	complete	oxide staining
A	54	2	8	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	54	2	2	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	oxide staining
A	54	2	2	*Myodes glareolus*	upper M1	R	complete	oxide staining
A	54	2	1	*Myodes glareolus*	upper M2	R	complete	
A	55	2	2	*Microtus arvalis/agrestis*	lower M1	R	complete	oxide staining
A	55	2	1	*Glis glis*	lower M2	L	nearly complete	
A	72	2	1	*Microtus arvalis/agrestis*	lower M1	L	complete	oxide staining
A	72	2	3	*Microtus arvalis/agrestis*	lower M1	R	complete	oxide staining
A	72	2	1	*Sorex araneus*	lower I1 (incisor 1)	L	complete	articulates with mandible and lower C
A	72	2	1	*Sorex araneus*	lower C (canine)	L	nearly complete	articulates with mandible and lower I1
A	72	2	1	*Sorex araneus*	mandible	L	complete	articulates with lower I1 and C; oxide staining
A	73	2	1	*Talpa europea*	humerus	L	complete	oxide staining

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	73	2	3	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	73	2	9	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	oxide staining
A	76	2	4	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	76	2	4	*Myodes glareolus*	lower M1	L	nearly complete	oxide staining
A	77	2	2	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	

A	77	2	5	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	77	2	2	*Myodes glareolus*	lower M2	L	complete	oxide staining
A	77	2	1	*Myodes glareolus*	lower M3	R	complete	oxide staining
A	77	2	1	*Myodes glareolus*	upper M3	L	complete	oxide staining
A	77	2	4	*Myodes glareolus*	lower M1	R	anterior half	oxide staining
A	103	2	6	*Myodes glareolus*	lower M1	R	complete	
A	103	2	7	*Myodes glareolus*	lower M1	L	complete	oxide staining
A	103	2	1	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	108	2	2	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	109	2	1	*Myodes glareolus*	lower M1	R	anterior half	oxide staining
A	112	2	1	*Apodemus flavicollis*	lower M1	L	complete	oxide staining
A	112	2	1	*Apodemus flavicollis*	upper M1	L	nearly complete	
A	112	2	7	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	112	2	2	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	122	2A	3	*Myodes glareolus*	lower M1	L	complete	oxide staining
A	122	2A	1	*Myodes glareolus*	upper M1	L	complete	oxide staining
A	122	2A	2	*Myodes glareolus*	upper M1	R	complete	oxide staining

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	122	2A	3	*Myodes glareolus*	lower M1	L	nearly complete	
A	122	2A	1	*Talpa europea*	humerus	R	proximal epiphysis and shaft (upper end and long part)	oxide staining
A	122	2A	4	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	124	2A	1	*Soricinae*	mandible	R	horizontal ramus	
A	124	2A	2	*Microtus arvalis/agrestis*	lower M1	L	complete	oxide staining
A	124	2A	3	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	oxide staining
A	124	2A	2	*Myodes glareolus*	lower M1	L	complete	
A	125	2A	1	*Myodes glareolus*	lower M1	R	complete	oxide staining
A	125	2A	5	*Myodes glareolus*	lower M1	L	nearly complete	oxide staining

A	125	2A	1	*Dicrostonyx torquatus*	lower M1	R	posterior half	oxide staining
A	126	2A	1	*Glis glis*	molar	-	half	oxide staining
A	126	2A	4	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	126	2A	1	*Microtus arvalis/agrestis*	lower M1	R	complete	oxide staining
A	138	3	1	*Dicrostonyx torquatus*	lower M1	L	distal (lower) half	
A	138	3	3	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	138	3	2	*Dicrostonyx torquatus*	lower M2	R	complete	
A	138	3	9	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	140	3	11	*Microtus arvalis/agrestis*	lower M1	R	complete	oxide staining
A	140	3	3	*Microtus gregalis*	lower M1	L	complete	
A	140	3	1	*Talpa europea*	radius (lower arm bone)	R	nearly complete	oxide staining

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	140	3	4	*Dicrostonyx torquatus*	lower M1	L	anterior half	
A	141	3	5	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	141	3	7	*Dicrostonyx torquatus*	upper M3	L	nearly complete	
A	141	3	1	*Dicrostonyx torquatus*	lower M3	R	complete	
A	143	3	2	*Dicrostonyx torquatus*	upper M1	L	complete	
A	143	3	2	*Microtus gregalis*	lower M1	L	nearly complete	
A	143	3	1	*Microtus gregalis*	lower M1	R	complete	oxide staining
A	143	3	2	*Dicrostonyx torquatus*	lower M2	R	complete	oxide staining
A	143	3	4	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	143	3	4	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	156	3	3	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	156	3	2	*Dicrostonyx torquatus*	upper M3	L	complete	

A	156	3	6	*Dicrostonyx torquatus*	upper M3	R	complete	
A	156	3	2	*Dicrostonyx torquatus*	lower M1	R	anterior half	
A	159	3	1	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	159	3	3	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	159	3	15	*Dicrostonyx torquatus*	lower M1	L	completenearly complete	
A	159	3	10	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	159	3	1	*Dicrostonyx torquatus*	lower M1	L	anterior half	
A	159	3	2	*Dicrostonyx torquatus*	upper M1	R	complete	
A	159	3	4	*Dicrostonyx torquatus*	lower M2	L	complete	oxide staining

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	160	3	4	*Microtus gregalis*	lower M1	L	nearly complete	
A	160	3	1	*Myodes glareolus*	upper M2	L	complete	
A	160	3	6	*Dicrostonyx torquatus*	upper M1	R	nearly complete	
A	160	3	3	*Dicrostonyx torquatus*	upper M1	L	complete	
A	160	3	1	*Dicrostonyx torquatus*	upper M2	L	complete	
A	160	3	3	*Dicrostonyx torquatus*	upper M3	L	complete	
A	160	3	2	*Dicrostonyx torquatus*	upper M3	R	complete	
A	160	3	5	*Dicrostonyx torquatus*	lower M1	L	nearly complete	oxide staining
A	160	3	8	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	160	3	7	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	160	3	4	*Microtus arvalis/agrestis*	lower M1	R	complete nearly complete	
A	163	3	2	*Microtus gregalis*	lower M1	L	nearly complete	
A	163	3	3	*Microtus gregalis*	lower M1	R	nearly complete	
A	163	3	2	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	

A	163	3	1	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	163	3	2	*Dicrostonyx torquatus*	lower M1	L	posterior half	oxide staining
A	163	3	4	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	163	3	4	*Dicrostonyx torquatus*	lower M2	L	nearly complete	
A	163	3	3	*Dicrostonyx torquatus*	lower M2	R	complete	
A	163	3	2	*Dicrostonyx torquatus*	lower M3	R	complete	
A	163	3	6	*Dicrostonyx torquatus*	upper M1	L	complete	
A	163	3	4	*Dicrostonyx torquatus*	upper M1	R	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	163	3	1	*Dicrostonyx torquatus*	upper M2	L	nearly complete	
A	163	3	4	*Dicrostonyx torquatus*	upper M3	L	complete	
A	163	3	1	*Dicrostonyx torquatus*	upper M3	R	complete	
A	163	3	1	*Neomys fodiens*	lower M2	L	complete	articulate with lower M1 and mandible
A	163	3	1	*Neomys fodiens*	lower M1	L	complete	articulate with lower M2 and mandible
A	163	3	1	*Neomys fodiens*	mandible	L	complete	articulate with lower M1 and M2
A	163	3	10	*Dicrostonyx torquatus*	lower M1	L	posterior half	
A	163	3	8	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	163	3	2	*Dicrostonyx torquatus*	lower M2	R	complete	
A	163	3	2	*Dicrostonyx torquatus*	upper M1	L	complete	
A	163	3	4	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	oxide staining
A	163	3	3	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	163	3	5	*Microtus gregalis*	lower M1	L	complete	oxide staining
A	184	3	4	*Dicrostonyx torquatus*	lower M1	L	nearly complete	

A	184	3	4	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	184	3	1	*Dicrostonyx torquatus*	small tooth fragment	NA	3 triangles	
A	184	3	2	*Dicrostonyx torquatus*	upper M1	L	nearly complete	
A	186	3	1	*Chionomys nivalis*	bacculum	NA	complete	
A	186	3	2	*Microtus arvalis/ agrestis*	lower M1	L	nearly complete	
A	186	3	3	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	186	3	2	*Dicrostonyx torquatus*	lower M1	L	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	186	3	1	*Dicrostonyx torquatus*	upper M1	L	complete	
A	189	3	9	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	189	3	11	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	189	3	2	*Dicrostonyx torquatus*	lower M2	L	complete	oxide staining
A	189	3	3	*Dicrostonyx torquatus*	lower M2	L	complete	
A	189	3	2	*Dicrostonyx torquatus*	upper M1	R	nearly complete	
A	189	3	3	*Microtus gregalis*	lower M1	L	complete	
A	189	3	1	*Microtus gregalis*	lower M1	R	complete	oxide staining
A	191	3	1	*Chionomys nivalis*	lower M1	L	complete	
A	191	3	4	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	191	3	5	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	191	3	3	*Dicrostonyx torquatus*	lower M2	R	complete	
A	191	3	1	*Dicrostonyx torquatus*	lower M3	R	complete	
A	191	3	2	*Dicrostonyx torquatus*	upper M3	R	complete	
A	191	3	2	*Microtus gregalis*	lower M1	L	complete	
A	220	4	12	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	220	4	7	*Dicrostonyx torquatus*	lower M1	R	anterior half	oxide staining

A	220	4	5	*Dicrostonyx torquatus*	lower M2	L	complete	
A	220	4	4	*Dicrostonyx torquatus*	lower M2	R	nearly complete	
A	220	4	2	*Dicrostonyx torquatus*	lower M3	L	complete	
A	220	4	8	*Dicrostonyx torquatus*	upper M1	L	complete	
A	220	4	11	*Dicrostonyx torquatus*	upper M1	R	complete	oxide staining
A	220	4	3	*Dicrostonyx torquatus*	upper M2	L	nearly complete	
A	220	4	4	*Dicrostonyx torquatus*	upper M3	L	complete	
A	220	4	2	*Dicrostonyx torquatus*	upper M3	R	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	220	4	7	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	220	4	9	*Microtus arvalis/agrestis*	lower M1	R	completenearly complete	
A	223	4	4	*Microtus arvalis/agrestis*	lower M1	L	completenearly complete	
A	223	4	8	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	223	4	1	*Dicrostonyx torquatus*	lower M1	L	posterior half	
A	223	4	9	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	223	4	3	*Dicrostonyx torquatus*	lower M2	L	complete	
A	223	4	1	*Dicrostonyx torquatus*	lower M3	R	complete	
A	223	4	6	*Dicrostonyx torquatus*	upper M1	L	complete	
A	223	4	7	*Dicrostonyx torquatus*	upper M1	R	complete	
A	223	4	2	*Dicrostonyx torquatus*	upper M2	L	nearly complete	
A	223	4	4	*Dicrostonyx torquatus*	upper M2	R	complete	
A	223	4	3	*Dicrostonyx torquatus*	upper M3	R	complete	
A	223	4	6	*Microtus gregalis*	lower M1	L	complete	
A	223	4	5	*Microtus gregalis*	lower M1	R	complete	

A	224	4	1	*Talpa europaea*	humerus	R	complete	
A	224	4	4	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	224	4	5	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	224	4	2	*Dicrostonyx torquatus*	upper M1	L	complete	
A	224	4	1	*Dicrostonyx torquatus*	upper M1	R	complete	
A	224	4	3	*Microtus arvalis/ agrestis*	lower M1	L	nearly complete	
A	224	4	3	*Microtus arvalis/ agrestis*	lower M1	R	complete	
A	228	4	3	*Microtus gregalis*	lower M1	L	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	228	4	1	*Glis glis*	upper M2	L	crown complete,roots broken	oxide staining
A	228	4	5	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	228	4	4	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	228	4	12	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	228	4	14	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	228	4	4	*Dicrostonyx torquatus*	lower M2	L	complete	
A	228	4	4	*Dicrostonyx torquatus*	lower M2	R	complete	
A	228	4	2	*Dicrostonyx torquatus*	lower M3	L	complete	
A	228	4	6	*Dicrostonyx torquatus*	upper M1	R	complete	
A	228	4	8	*Dicrostonyx torquatus*	upper M1	L	complete	
A	228	4	2	*Dicrostonyx torquatus*	upper M2	L	complete	
A	228	4	2	*Dicrostonyx torquatus*	upper M2	R	nearly complete	
A	228	4	2	*Dicrostonyx torquatus*	upper M3	L	complete	
A	228	4	3	*Dicrostonyx torquatus*	lower M1	R	posterior half	
A	249	4	2	*Dicrostonyx torquatus*	upper M3	L	complete	oxide staining

A	249	4	1	*Dicrostonyx torquatus*	upper M3	R	complete	
A	249	4	2	*Dicrostonyx torquatus*	upper M2	L	nearly complete	
A	249	4	2	*Dicrostonyx torquatus*	upper M1	L	nearly complete	
A	249	4	2	*Dicrostonyx torquatus*	upper M1	R	complete	
A	249	4	1	*Dicrostonyx torquatus*	lower M3	L	complete	
A	249	4	1	*Dicrostonyx torquatus*	lower M3	R	complete	
A	249	4	3	*Dicrostonyx torquatus*	lower M2	L	nearly complete	
A	249	4	5	*Dicrostonyx torquatus*	lower M2	R	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	249	4	7	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	249	4	11	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	249	4	4	*Microtus arvalis/agrestis*	lower M1	L	complete	oxide staining
A	249	4	4	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	251	4	3	*Microtus gregalis*	lower M1	L	complete	
A	251	4	7	*Microtus gregalis*	lower M1	R	complete	
A	251	4	4	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	251	4	5	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	251	4	1	*Dicrostonyx torquatus*	upper M3	R	complete	
A	251	4	1	*Dicrostonyx torquatus*	upper M1	R	nearly complete	
A	251	4	4	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	252	4	1	*Microtus arvalis/agrestis*	lower M1	L	complete	
A	252	4	6	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	252	4	2	*Dicrostonyx torquatus*	lower M1	L	anterior half	
A	252	4	8	*Dicrostonyx torquatus*	lower M1	L	nearly complete	

A	252		4	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	257	4	1	*Chionomys nivalis*	lower M1	R	complete	
A	257	4	2	*Dicrostonyx torquatus*	lower M1	R	anterior half	
A	257	4	4	*Dicrostonyx torquatus*	lower M1	R	nearly complete	
A	257	4	1	*Dicrostonyx torquatus*	lower M1	L	complete	
A	257	4	2	*Dicrostonyx torquatus*	upper M1	R	complete	
A	257	4	2	*Dicrostonyx torquatus*	upper M1	L	complete	
A	257	4	2	*Microtus gregalis*	lower M1	L	complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	257	4	3	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	299	4	2	*Dicrostonyx torquatus*	lower M2	L	nearly complete	
A	299	4	1	*Soricinae*	lower M2	L	nearly complete	
A	299	4	2	*Dicrostonyx torquatus*	lower M3	R	complete	
A	299	4	4	*Dicrostonyx torquatus*	lower M1	R	nearly complete	oxide staining
A	299	4	1	*Dicrostonyx torquatus*	upper M1	L	complete	
A	299	4	2	*Dicrostonyx torquatus*	upper M3	L	complete	
A	299	4	3	*Dicrostonyx torquatus*	upper M3	R	complete	
A	300	4	4	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	300	4	1	*Dicrostonyx torquatus*	lower M2	L	complete	
A	300	4	1	*Microtus agrestis*	upper M2	R	complete	
A	300	4	3	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	300	4	2	*Microtus arvalis/agrestis*	lower M1	R	complete	
A	304	4	9	*Dicrostonyx torquatus*	lower M1	L	nearly complete	
A	304	4	12	*Dicrostonyx torquatus*	lower M1	R	nearly complete	

A	304	4	2	*Dicrostonyx torquatus*	lower M1	R	posterior half	
A	304	4	4	*Dicrostonyx torquatus*	lower M1	R	anterior half	oxide staining
A	304	4	4	*Dicrostonyx torquatus*	lower M2	L	complete	
A	304	4	5	*Dicrostonyx torquatus*	lower M2	R	complete	
A	304	4	3	*Dicrostonyx torquatus*	lower M3	L	complete	
A	304	4	1	*Dicrostonyx torquatus*	lower M3	R	complete	
A	304	4	7	*Dicrostonyx torquatus*	upper M1	L	nearly complete	
A	304	4	10	*Dicrostonyx torquatus*	upper M1	R	nearly complete	

Quad.	Find #	Arch. Horizon	#	Taxon	Element	Side	Portion	Comment
A	304	4	1	*Dicrostonyx torquatus*	upper M2	L	complete	articulate with maxilla and upper M3
A	304	4	1	*Dicrostonyx torquatus*	upper M3	L	complete	articulate with maxilla and upper M2
A	304	4	1	*Dicrostonyx torquatus*	maxilla (upper jaw bone)	L	only tooth row	articulate with upper M2 and M3
A	304	4	2	*Dicrostonyx torquatus*	upper M2	L	complete	
A	304	4	4	*Dicrostonyx torquatus*	upper M2	R	nearly complete	
A	304	4	1	*Dicrostonyx torquatus*	upper M3	L	complete	
A	304	4	4	*Dicrostonyx torquatus*	upper M3	R	complete	
A	304	4	4	*Microtus arvalis/agrestis*	lower M1	L	nearly complete	
A	304	4	7	*Microtus arvalis/agrestis*	lower M1	R	nearly complete	
A	304	4	6	*Microtus gregalis*	lower M1	L	nearly complete	
A	304	4	6	*Microtus gregalis*	lower M1	R	nearly complete	
A	305	4	6	*Dicrostonyx torquatus*	lower M1	R	complete	
A	305	4	2	*Dicrostonyx torquatus*	lower M1	L	posterior half	

A	305	4	1	*Dicrostonyx torquatus*	lower M2	R	nearly complete	
A	305	4	2	*Dicrostonyx torquatus*	upper M1	L	complete	
A	305	4	3	*Dicrostonyx torquatus*	upper M1	R	nearly complete	
A	305	4	3	*Dicrostonyx torquatus*	upper M3	L	complete	
A	305	4	2	*Microtus arvalis/ agrestis*	lower M1	L	nearly complete	
A	305	4	4	*Microtus arvalis/ agrestis*	lower M1	R	nearly complete	
A	305	4	1	*Microtus arvalis/ agrestis*	lower M1	R	complete	articulate with mandible

Quad.	**Find #**	**Arch. Horizon**	**#**	**Taxon**	**Element**	**Side**	**Portion**	**Comment**
A	305	4	1	*Microtus arvalis/agrestis*	mandible	R	nearly complete	articulate with lower M1

CHAPTER OVERVIEW

8: Primate Evolution

Learning Objectives

- Describe the characteristics of specific fossil primates
- Compare miocene ape fossils
- Identify radiation patterns in the fossil record
- Explain cladistic relationships
- Hypothesize about relationships between fossil primates and contemporary apes

8.1: Fossil Primates

Fossil Primates

Format: In-person or online

Author: Beth Shook

Modified from labs by McHenry, Henry M., University of California, Davis.

Time needed: 60 minutes

Supplies Needed

- Primate fossil replicas or 3D images of: *Aegyptopithecus*, *Proconsul*, *Sivapithecus*, and *Gigantopithecus*
- Extant primate skulls (real or casts) or 3D images of extant primate skulls
- Handouts or websites with information about plesiadapis, omomyids, adapids

Readings

- Perry, Jonathan and Stephanie Canington. 2019. Chapter 8: Primate Evolution. *Explorations.*

Introduction

This lab covers primate evolution from the Paleocene through the Miocene, with an emphasis on the Miocene apes.

- Station 1: The Paleocene (covers Plesiadapiforms)
- Station 2: The Eocene & first true primates (Omomyids and Adapids)
- Station 3: Oligocene (covers *Aegyptopithecus*)
- Station 4: Miocene & *Proconsul*
- Station 5: Miocene & *Sivapithecus*
- Station 6: Miocene & *Gigantopithecus*

Steps

- Before beginning this lab, the instructor should select skeletal materials, casts, or images of skeletal materials for students, and arrange them at various stations. All skeletal materials should be labeled with cards/small labels with terms that match the student worksheets (e.g. Primate, Strepsirrhine). At some stations a handout, website, or textbook passage will need to be provided to give students the information to answer the questions. Alternatively, virtual images can be linked to the student worksheet to create a virtual lab.
- Specific materials needed are:
  - Station 1: handout, website, or textbook passage containing information about the characteristics of Plesiadapiforms.
  - Station 2: handout, website, or textbook passage containing information about the characteristics omomyids and adapids shared with primates.
  - Station 3: (a) strepsirrhine (e.g. lemur) skull, (b) Old World monkey skull, (c) ape skull, (d) aegyptopithecus skull, and (e) images of these primates or primate skeletons to allow comparison between their forelimb and hindlimb length. Extant primate skulls should allow visibility of molar cusp patterns.
  - Station 4: (a) monkey skull, (b) ape skull, (c) human skull, and (d) proconsul skull. Extant primate skulls should allow visibility of molar cusp patterns.
  - Station 5: (a) African ape skull, (b) orangutan skull, and (c) *Sivapithecus* skull.
  - Station 6: (a) *Gigantopithecus* teeth and/or jaw, (b) Gorilla skull, and (c) human skull
- The instructor should choose to assign this lab as an individual or small group activity.
- An introduction to encourage students to think about the “big picture” events from each time period is helpful. Instructors should be sure students are familiar with the traits in the lab (e.g. dental arcade, Y5 or bilophodont molar cusp patterns) or are given resources to identify these traits at the various stations.
- The lab consists of six “stations.” Stations can be completed in any order, however there is a “Miocene” phylogeny that requires the completion of stations four through six first.
  - Station 1: Using the resources provided by the instructor, students compare plesiadapiforms and primates.
  - Station 2: Using images provided of omomyids and adapids, students complete the yes/no table on the Worksheet.

- Station 3: Given the scenario described on the worksheet, and observation of *Aegyptopithecus* fossils or images, students complete the table.
- Station 4-6: Students examine fossils from the Miocene (*Proconsul*, *Sivapithecus*, and *Gigantopithecus*) in order to complete the Worksheet questions.

Conclusion

- Instructors should have students report to the class on their answers for some/all of the stations. For example, each group could complete a small table for one station on the board. While some parts of the tables are more open ended, there are some traits that instructors will want to be sure students identified correctly.
- Instructors should connect the fossils with what we know of the primate phylogeny. For example, traits shared among most/all primates are seen in the earliest fossils.
- Specifically, the primate phylogeny that goes with Stations 4-6 should be covered during the wrap-up. Students can hypothesize, based on the lab, where they would put these fossils. Instructors can then discuss the locations that primatologists are placing them - recognizing that there is not always agreement.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This lab can be adapted by utilizing 3-D images of extant primates and primate fossils available at such sites as Sketchfab https://sketchfab.com/ (all the fossils and extant primates utilized in this lab), eSkeletons http://www.eskeletons.org/ (all extant primates in this lab), and/or African Fossils https://africanfossils.org/ (some fossils and some extant primates in this lab).

Morphosource https://www.morphosource.org/ by Duke University also has a collection of 3-D fossil images.

For Further Exploration

Dunsworth, Holly. 2015. How to Become a Primate Fossil. *Nature Education Knowledge* 6(7):1 https://www.nature.com/scitable/knowledge/library/how-to-become-a-primate-fossil-135630567/

Slicox, Mary T. 2014. Primate Origins and the Plesiadapiforms. *Nature Education Knowledge* 5(3):1 https://www.nature.com/scitable/knowledge/library/primate-origins-and-the-plesiadapiforms-106236783/

Talking Science. 2016. Gaga for Gigantopithecus. https://www.youtube.com/watch?v=mzhbvZB7e7Y

References

Perry, Jonathan and Stephanie Canington. 2019. “Chapter 8: Primate Evolution.” *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Fossil Primates

Station 1: The Paleocene (Approximately 65 - 54 MYA): Primate-Like Mammals

Below is a reconstruction of *Plesiadapis*. These small quadrupeds came in many diverse forms, and represent part of the mammalian radiation that occurred in the Paleocene. They may be relatives of primates (a side branch), or some of them were perhaps even ancestral to primates as some of them have the auditory bulla, which contains the middle ear and is distinctive of primates.

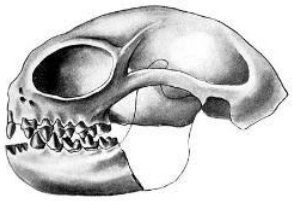
Plesiadapis tricuspidens by Nobu Tamura (Spinops) is under a CC BY-NC-ND 3.0 License.

Plesiadapiforms lived in western North America, western Europe, Asia, and Africa at the start of the Paleocene. While at the right time to be early primates, they lack true primate characteristics.

Using the resources provided for you, what are four differences between plesiadapiforms and primates?

Station 2: The Eocene (Approximately 55 - 34 MYA): The First True Primates

In the Eocene, there were two early primate groups represented by the fossil record: omomyids and adapids.



The skull of *Anaptomorphus* (an omomyid). Hubrecht A.A.W. The descent of the primates. Lectures delivered on the occasion of the sesquicentennial celebration of Princeton University. New York: Charles Scribner's Sons, 1897. U.S. Public Domain.

Life restoration of *Tetonius homunculus* (an omomyid) from W.B. Scott's (1858–1947). A History of Land Mammals in the Western Hemisphere. New York: The Macmillan Company. U.S. Public Domain.

Examine the pictures above, and the provided resources, to determine which of the following traits **omomyids** and **adapids** have that indicate they are primates. Please mark "yes" if at least one of the above primates exhibits the trait.

Shared with Primates	**Yes or No?**
Partially or fully enclosed eye orbits?	
Eyes that are convergent (look forward)?	
Small incisors and large canines?	
Short snout?	
Increased brain size?	
Grasping hands?	

Station 3: The Oligocene (Approximately 34 - 24 MYA): An Adaptive Radiation of Anthropoids

In the Oligocene, tropical rain forests extended far into areas that are now temperate zones. One of the best Oligocene fossil deposits is in the Egyptian desert—at a place called the Fayum. At one time this was an ideal habitat for anthropoid primates; a sluggish river delta surrounded by lush forest provided niches for several primate species.

In the 1960's Dr. Elwyn Simons and a Yale expedition discovered a nearly complete skull of *Aegyptopithecus*. Simons maintained that *Aegyptopithecus* was the earliest ape, a member of the superfamily *Hominoidea*. Today most dispute this assertion and argue that *Aegyptopithecus* has a mosaic of features suggesting it was probably a primitive catarrhine. Compare the provided strepsirrhine, monkey, and ape skulls to *Aegyptopithecus*.

	Strepsirrhine	**Old World Monkey**	**Ape**	***Aegyptopithecus***
Eye orbit size & orientation				
Brain size				
Snout length (compared to cranial size)				
Lower molar cusp pattern (Y5 or bilophodont)	N/A			
Front to hind limb ratio				Equal length suggesting a slow arboreal quadruped

Which traits might Simons have regarded as hominoid (ape & human) like?

We now know that the ancestor of apes and Old World monkeys had the Y-5 molar cusp pattern. For the hominoid (ape & human) clade, then, is Y-5 a derived trait or primitive trait?

Station 4: The Miocene: *Proconsul*

Proconsul is well known from Early Middle Miocene sites (22-17 mya) in East Africa. Examine the teeth and jaws of *Proconsul*.

	Monkey	**Ape**	**Human**	***Proconsul***
Lower molar cusp pattern (Y5 or bilophodont)				
Shape of dental arcade				
Canine size				

In its teeth and jaws, does *Proconsul* resemble an ape, a monkey, or human?

As ape-like as the jaws and teeth appear to be, the postcrania (skeleton) is very monkey-like. Detailed studies of the forelimb of *Proconsul* have shown that it lacked the brachiation ability present in living hominoid elbows and wrists. This is evidence that the common ancestor of living hominoids (gibbons, great apes, and humans) appeared after *Proconsul*.

Station 5: The Miocene: *Sivapithecus*

Sivapithecus lived in Asia between 12 and 8 MYA.

	An African Ape	**Orangutan**	***Sivapithecus***
Draw the overall shape of skull when viewed from side			
Eye orbit shape			
Closeness of eyes			

There are a lot of similarities between *Sivapithecus* and orangutans of today! There are some differences, though, including differences in their arm bones. *Sivapithecus* was probably closely related to, but perhaps not directly ancestral to, orangutans.

Station 6: The Miocene: *Gigantopithecus*

Gigantopithecus, which means "giant ape", has been found in China, India, and Vietnam, dating as far back as 8 MYA, but as recent as 500,000 YA.

Compare *Gigantopithecus* teeth and jaw to a Gorilla and a human. What similarities do you see? What differences do you see?

What type of diet do you think *Gigantopithecus* subsisted on? Why do you think that?

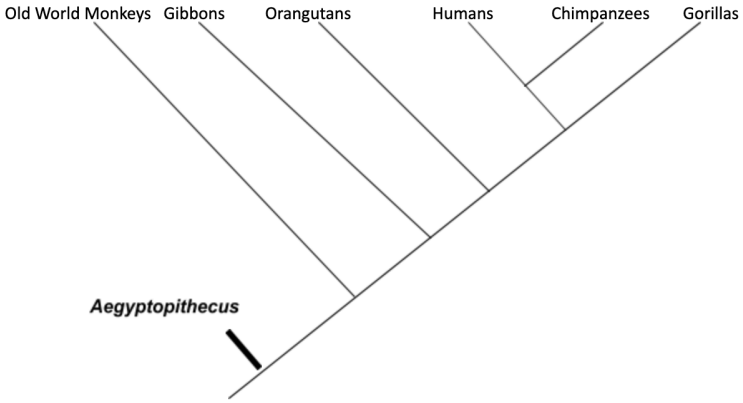
Station 4 - 6: The Miocene (Approximately 24 - 5 MYA): An Radiation of Apes

The Miocene was warmer and wetter than the present period. Apes were found in relative abundance in Africa and Eurasia in the Miocene. *Proconsul* was among the earliest (in Africa), and after *Proconsul* the apes spread and diversified: *Dryopithecus* in Europe, *Sivapithecus* and *Gigantopithecus* in Asia.

When you have finished looking at all of the fossils from the Miocene:

1) Draw a circle around the *hominoid* clade, and

2) After completing stations 4-6, mark where you think the fossil primates *Proconsul*, *Sivapithecus*, and *Gigantopithecus* best fit. Note: because they are fossils, they do not need to be listed at the top with the other primates, but can be drawn onto any lineage or as a side branch. *Aegyptopithecus* is drawn in as an example.



8.2: Prehistoric Primate Museum

Prehistoric Primate Museum

Format: In-person or online

Megaladapis in a virtual museum of anthropology

Author: Dr. Keith Chan

Time needed: ~30 minutes

Learning Objectives

- Identify scale models of prehistoric primates
- Examine traits of prehistoric primates
- Infer the adaptations of extinct primates

Supplies Needed

- Computer, smartphone, or VR goggles (optimal)
- Internet connection
- www.anvropomotron.com
- Worksheet (attached)

Readings

- Perry, Jonathan M. G. and Canington, Stephanie L. 2019. Chapter 8: Primate Evolution. *Explorations*.

Introduction

In this activity we will look at exhibits in AnVRopomotron.com, an online virtual anthropology museum created by Dr. Keith Chan. Our focus will be on the fossils and reconstructions of prehistoric primates that predate hominins. Students will answer questions by finding information presented in the virtual museum along with their own thinking about primate evolution and paleoanthropology based on lectures and readings.

AnVRopomotron can be viewed on web browsers on a variety of devices with different control schemes. A computer with a mouse and keyboard will provide a good experience. When available, a virtual reality headset with touch controls is optimal. A smartphone with touch controls is less ideal due to the small screen.

Steps

1. Students can work individually or in teams, but be sure to each take turns in order to experience the museum if working in a group.
2. Part 1: Students load the AnVRopomotron website and go straight ahead to the centerpiece model in front of them, with Gigantopithecus, Lucy, Homo sapiens, and Archicebus. Interacting with the orange orb will bring up info boxes on each statue. Questions on the worksheet use this information.
3. Part 2: Then, students can use their controls to go right and behind the wall to the “Grab Lab.” Students should browse the leftmost of the four tables, labeled “Pre-Homo.” They can interact with each object to bring up info boxes to help them answer the questions on the Worksheet.

4. Part 3: Students can leave the “Grab Lab,” walk past the centerpiece, and into the Scale Model Hall. After the gibbon, there are models of prehistoric primates, including Proconsul, Notharctus, and Megaladapis. More orange orbs bring up information on each species to help students answer the questions on the Worksheet.

Review Questions

The activity allows students to visualize prehistoric primates in a way that is connected to their own perception and exploration. Here are some areas to direct a discussion at the conclusion of this lab:

1. Which traits do the prehistoric primate models have in common? What are differences among them?
2. What decisions did the modeler have to make in reconstructing extinct life based on fossils?
3. Which other fossils and models should be included to cover the span of primate evolution?

Adapting for Online Learning

Rank how adaptable to online learning this lab is:

If applicable, include tips and suggestions on how to adapt this lab for online learning: Students could browse the exhibits and answer the questions on their own using their own device.

Tips and Suggestions

Browse the AnVRopomotron site on your own to get used to the controls and the layout of the museum. Students into gaming should be able to pick up the controls quickly but others may need help.

References

Perry, Jonathan M. G. and Canington, Stephanie L. 2019. “Chapter 8: Primate Evolution.” *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Chan, Keith. (2020). Megaladapis. CC BY-NC.

AnVRopomotron Worksheet

Part 1. Introduction and The Centerpiece

Go to www.anvropomotron.com on your device and use the controls to move around. The different controls for different devices are listed on the wall you are facing:

- Computer web browser: Use the WASD keys to move and drag with the mouse to look around.
- Smartphone: Press on the screen to move forward. Press with two fingers to move backward. Enable motion controls to tilt your phone to look around. Otherwise, swipe with your finger to look.
- Virtual Reality: Use thumbsticks to move. Turn your head and body to look around.

Go straight ahead to examine the bronze centerpiece. Touch the orange orb to make info panels appear. Answer these questions:

1. Which primate is the largest one shown in the centerpiece?

2. Which primate is the smallest?

3. Where is the smallest primate in the centerpiece?

Part 2. VR Grab Lab and Height Chart

Facing the front of the centerpiece, turn right and go into the VR Grab Lab. Go past the two tables and turn the corner to face the back wall that features four tables. We will be working with the far left table, labeled “Early Primate Fossils.” Touch the items to bring up information on the back wall and a magnified view. First, touch the Archicebus model to the far left of the table. Then, answer these questions.

4. How long ago did Archicebus live?

5. What was its most likely diet?

6. Examine the model: Archicebus looks a lot like a mouse, but it definitely has primate traits. What are some primate traits you see on the model?

Now examine the brown partial cranium next to Archicebus. Touch it to bring up its information.

7. What is the scientific name of this fossil?

8. Use your reasoning to answer this question: why is this fossil so broken and distorted? To answer, think about how an object becomes a fossil.

We are done with this section. Turn around and walk back to the first room. Go past the centerpiece to the height chart on the wall. Go up to it and answer this question.

9. Who was taller: Gigantopithecus or the tallest recorded person?

Part 3. Scale Model Hall

From the Height Chart, turn right and then turn left under the gibbon to enter the Scale Model Hall. There are a few models of prehistoric primates. Go to the one closest to you, which is on top of a tree branch and facing you. Touch its orb to bring up some information. The name should be familiar because the species represented by this model is closely related to the brown cranium you saw earlier. The model is based on multiple individuals and allows us a look at the full body.

10. Where were proconsulids found?

11. Which trait did proconsulids lack that makes them similar to modern apes? If you need a hint, use the gibbon model to compare.

12. Use your reasoning to answer this question: Proconsulids are only known from fossilized bones and teeth so no one knows exactly what a living one would look like. Which traits must have been inferred to reconstruct what a living Proconsul looked like?

Move past Proconsul further into the hall and look left and up for the next model. It is Notharctus. Touch its orb for info.

13. Where was this primate discovered and how many years ago did it live?

14. Which lineage of modern primates does Notharctus resemble the most?

15. Use your reasoning to answer this question: how could the long tail of this primate be an adaptation?

Keep moving to the next model, a larger primate clinging to a tree trunk. It is Megaladapis. Click its orb for information.

16. What is this primate's nickname due to it having similar adaptations as another animal?

17. Megaladapis existed until the first *Homo sapiens* arrived and settled its home island of Madagascar. Use your reasoning to answer this question: Why do you think this primate became extinct?

18. Also use your reasoning here: Which modern primate looks the most like Megaladapis? How did you choose this primate?

Part 4. Summary

Thinking about the exhibits you have seen, put some of the information together by answering the following questions.

19. Relatively, who lived first, second, and third in time: Proconsul, Archicebus, and Notharctus?

20. How did Gigantopithecus differ from other prehistoric primates in terms of their preferred environment? (Hint: Think about how the models are posed.)

8.3: Extant and Fossil Catarrhine Morphology

Extant and Fossil Catarrhine Morphology

Format: In-person and online

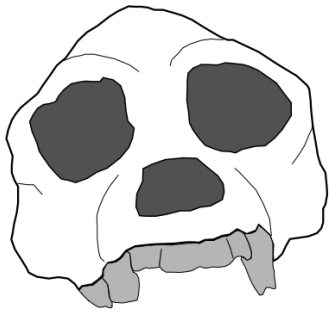


Figure 1. Tracing of *Aegyptopithecus* cranium.

Authors:

Zana R. Sims and Stephanie L. Canington

Time needed: 60 minutes

Learning Objectives

- Identify and describe some features of extant catarrhine morphology
- Compare cercopithecoid and hominoid traits
- Form hypotheses regarding ancestral traits of cercopithecoids and catarrhines
- Test hypotheses using fossil primate material

Supplies Needed

- Three extant primate skulls (bone or cast), 3D models, or photographs from multiple views of: *Papio* (one male, one female) and *Pan* (any)
- Two fossil primate skull casts, 3D models, or photographs from multiple views of: *Victoriapithecus* and *Aegyptopithecus*

Readings

- Perry, Jonathan and Stephanie Canington. 2019. Chapter 8: Primate Evolution. *Explorations.*
- Organ, Jason and Jessica Byram. 2019. Chapter 17: Osteology. *Explorations*.

Introduction

This lab allows students to familiarize themselves with characteristic features of extant catarrhines and to use this knowledge to analyze fossil catarrhine material from the Miocene and Oligocene. The instructor may choose to assign this lab as an individual or paired activity. Prior to starting this activity, the instructors should ensure student familiarity with general primate traits, or provide additional resources to assist students with their identification (e.g. molar cusp patterns, sexual dimorphism, primate diet).

Steps

1. Instructors should assemble all material prior to the start of this lab. Be sure to provide labels for extant material with genus and sex (e.g. *Papio*, male). If the lab will be performed virtually, include website links to 3D models or photographs on the worksheet.

    Materials Required:

    - Section 1: Student worksheet, textbook chapter, and
        - **Online Sources:** 3D tooth models; Additional Material 2
        - **In-person Material:** *Papio* and *Pan* skulls or dental casts
    - Section 2: Student worksheet, textbook chapter, and
        - **Online Sources:** Figure 2; Additional Material 1

    - **In-person Material:** *Papio* skulls or skull casts
- Section 3: Student worksheet
- Section 4: Student worksheet, textbook chapter and
    - **Online Sources:** Photographs of *Victoriapithecus* and *Aegyptopithecus* publications. See References for details
    - **In-person Material:** *Victoriapithecus* and *Aegyptopithecus* skull casts

2. This lab is subdivided into four sections. Students should first complete the activities for the extant material and hypothesis writing (sections 1-3) before moving on to examining the fossil material.
    - Section 1: Students use the provided cranial material to describe and compare two catarrhines, the cercopithecoid *Papio* and the hominoid *Pan*, guided by questions from the worksheet.
    - Section 2: Students use the provided material to compare the male and female crania of *Papio*, guided by questions from the worksheet.
    - Section 3: Based on the previous sections, students form hypotheses about the ancestral traits of cercopithecoids and then the ancestral traits of all catarrhines.
    - Section 4: Students will use the provided material to compare their hypotheses to the fossils of *Victoriapithecus* and *Aegyptopithecus*.

Conclusion

After completing this lab, students should be able to identify key features of catarrhine primates, including distinguishing between cercopithecoids and hominoids. Students should also have a sense of how knowledge about extant taxa can be applied to identify and interpret fossil primates.

- To wrap-up the lab, instructors should ask students to discuss their findings from the comparison of *Papio* and *Pan*. What defines cercopithecoids? What defines hominoids? What do they share?
- Instructors should initiate a discussion about the role of sexual dimorphism in primate features and in fossil primate interpretations.
- Finally, instructors should ask students to share the hypotheses they created in Section 3 for the ancestor of cercopithecoids like *Papio*, and the common ancestor of all catarrhines including *Papio* and *Pan*. Does the fossil *Victoriapithecus* have any features you described in your hypothesis for the ancestor of the cercopithecoid *Papio*? Does the fossil *Aegyptopithecus* have any features you described in your hypothesis for the common ancestor of *Papio* and *Pan*? Instructors can use this opportunity to introduce the concepts of primitive and derived traits, cladistics, primate phylogenetics, or to discuss the complex process of fossil recovery and interpretation.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it is (mark in bold):

To adapt this lab for online learning, use 3D images, models, or photographs of the extant and fossil primates. See Supplemental E-Materials for instructions regarding access and links.

For Further Exploration

Cartmill, Matt. 2012. “Primate origins, human origins, and the end of higher taxa.” *Evolutionary Anthropology: Issues, News, and Reviews*, 21(6): 208-220. https://onlinelibrary.wiley.com/doi/full/10.1002/evan.21324

MacLatchy, Laura M, William Joseph Sanders and Craig L. Wuthrich. 2015. “Hominoid Origins.” *Nature Education Knowledge* 6(7): 4. https://www.nature.com/scitable/knowledge/library/hominoid-origins-135874580/

Rasmussen, D. Tab, Anthony R. Friscia, Mercedes Gutierrez, John Kappelman, Ellen R. Miller, Samuel Muteti, Dawn Reynoso et al. 2019. "Primitive Old World monkey from the earliest Miocene of Kenya and the evolution of cercopithecoid bilophodonty." *Proceedings of the National Academy of Sciences* 116(13): 6051-6056. https://doi.org/10.1073/pnas.1815423116.

Zichello, Julia M., Karen L. Baab, Kieran P. McNulty, Christopher J. Raxworthy, and Michael E. Steiper. 2018. "Hominoid intraspecific cranial variation mirrors neutral genetic diversity." *Proceedings of the National Academy of Sciences* 115(45): 11501-11506. https://doi.org/10.1073/pnas.1802651115.

Zinner, Dietmar and Christian Roos. 2014. “So what is a species anyway? A primatological perspective.” *Evolutionary Anthropology: Issues, News, and Reviews*, 23(1): 21-23. https://onlinelibrary.wiley.com/doi/full/10.1002/evan.21390

References

Benefit, Brenda R. and Monte L. McCrossin. 1997. "Earliest known Old World monkey skull." *Nature* 388 (6640): 368-371. https://doi.org/10.1038/41078.

Simons, Elwyn L., Erik R. Seiffert, Timothy M. Ryan, and Yousry Attia. 2007. "A remarkable female cranium of the early Oligocene anthropoid *Aegyptopithecus zeuxis* (Catarrhini, Propliopithecidae)." *Proceedings of the National Academy of Sciences* 104(21): 8731-8736. https://doi.org/10.1073/pnas.0703129104.

Image Attributions

Figure 1. Tracing of *Aegyptopithecus*, a derived work by Zana Sims and Stephanie Canington is under a CC BY-NC 4.0 License. [Redrawn from Fossil of *Aegyptopithecus*, by Ghedoghedo, CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Aegyptopithecus_zeuxis_paris.jpg#file].

Figure 2. Comparative catarrhine morphology, a derived work by Zana Sims and Stephanie Canington is under a CC BY-NC 4.0 License. [Includes (**A**) *Pan troglodytes* [background removed] by Klaus Rassinger and Gerhard Cammerer, CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Pan_troglodytes_01_MWNH_230.jpg; (**B**) *Papio ursinus* [background removed] by Klaus Rassinger and Gerhard Cammerer, CC BY-SA 3.0. https://commons.wikimedia.org/wiki/File:Papio_ursinus_02_MWNH_715b.jpg].

Figure 2. *Papio anubis* sexual dimorphism, a derived work by Zana Sims and Stephanie Canington is under a CC BY-NC 4.0 License. [Includes *Papio anubis* male and female skull in (**A**) anterior view [contrast enhanced] by Emőke Dénes, CC BY-SA 4.0. https://commons.wikimedia.org/wiki/File:Papio_anubis_skulls.jpg; (**B**) oblique lateral view [contrast enhanced] by Emőke Dénes, CC BY-SA 4.0. https://commons.wikimedia.org/wiki/File:Papio_anubis_skulls_2.jpg].

Extant and Fossil Catarrhine Morphology Worksheet

Section 1: Cercopithecoid vs Hominoid

Compare the crania of two catarrhine primates, *Papio* and *Pan*. List at least one difference you see in the:

- shape and position of the orbits
- nasal aperture and rostrum
- neurocranium

***Papio* (Baboon)**	***Pan* (Chimpanzee)**

Other than body size, can you think of some other reasons why crania of these primates might look so different from each other?

Now compare the molars of *Papio* and *Pan*:

- How many cusps do they each have on the upper M2 (second molar)?
- Do you notice any differences in the shape of the teeth? What about their sizes?
- What molar cusp pattern does each primate have?
- What might be the function of these molar cusp patterns?

***Papio* (Baboon)**	***Pan* (Chimpanzee)**

Papio has very large canines, what purpose do you think this serves? What are the advantages and disadvantages of such big teeth?

Do you think the trait of large canines may have been the same throughout the evolutionary history of cercopithecoids?

How would you determine whether large canine size is a trait seen throughout the evolutionary history of cercopithecoids or if it is a recent development?

Section 2: Sexual Dimorphism: How Does Sex Influence Shape?

Examine the two crania of *Papio*: the larger is a male and the smaller is a female. Describe any other differences in their features that you see.

Male *Papio* (Baboon)	**Female *Papio* (Baboon)**

If you found two fossils with the features you identified in above for the male and female crania of *Papio*, would you think they were from the same genus? Would you assign them to the same species? What evidence would you use to support your classification of the fossils?

Section 3: How Do You Define an Ancestor?

Based on some of the features you have examined, what do you think the ancestor of *Papio* looked like? Which features of the cranium might look the same as the modern species? Which features might look different?

What do you think the common ancestor of *Papio* and *Pan* looked like? Are there any features that *Papio* and *Pan* have in common today that you think their ancestor might have shared? Might any features be absent?

Section 4: Putting Your Hypotheses to the Test: Fossil Evidence

Examine the hypothesized ancestor of cercopithecoids like *Papio*, *Victoriapithecus* (~19-12.5 MYA), from the early middle Miocene of East Africa. Did you identify any of the ancestral traits present in this specimen in your hypotheses from Section 3 for the ancestor of *Papio*? Which ones?

Do you think this fossil is likely to be the ancestor of *Papio*? Why or why not?

Now, look at the hypothesized ancestor for both *Papio* and *Pan*, *Aegyptopithecus* (~30-29 MYA), from the early Oligocene of Egypt. Did you identify any of the ancestral traits present in this specimen in your hypotheses from Section 3 for the common ancestor of *Papio* and *Pan*? Which ones?

Make the case for or against *Aegyptopithecus* as the ancestor for both catarrhines *Papio* and *Pan*. Use at least four shared traits to support your argument for *Aegyptopithecus* being an ancestor of *Papio* and *Pan*, **OR** use at least four independent traits to support your argument against *Aegyptopithecus* being an ancestor of *Papio* and *Pan*.

Figures and Lab Material

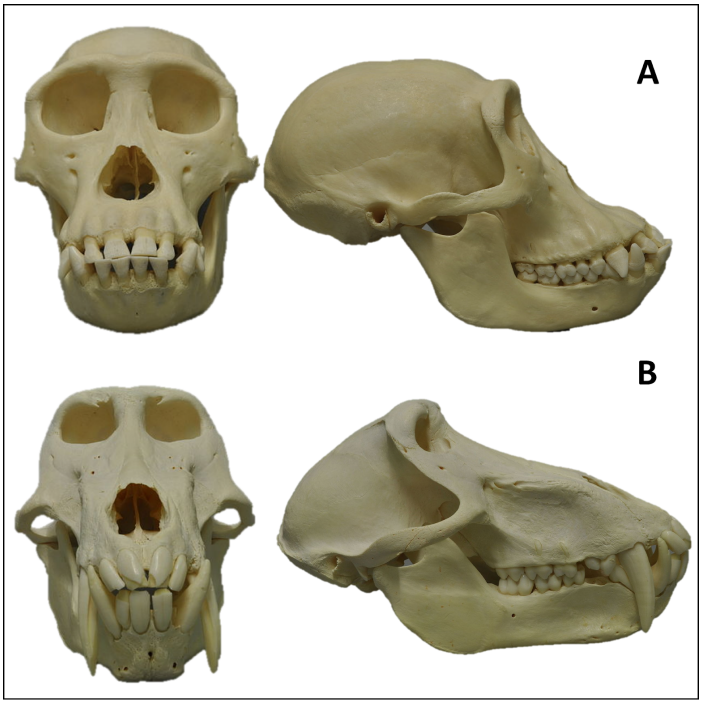


Figure 2. Anterior (forward-facing) and lateral (side) views of the skulls of: **A** - a female chimpanzee (*Pan troglodytes*) and **B** - a male chacma baboon (*Papio ursinus*).

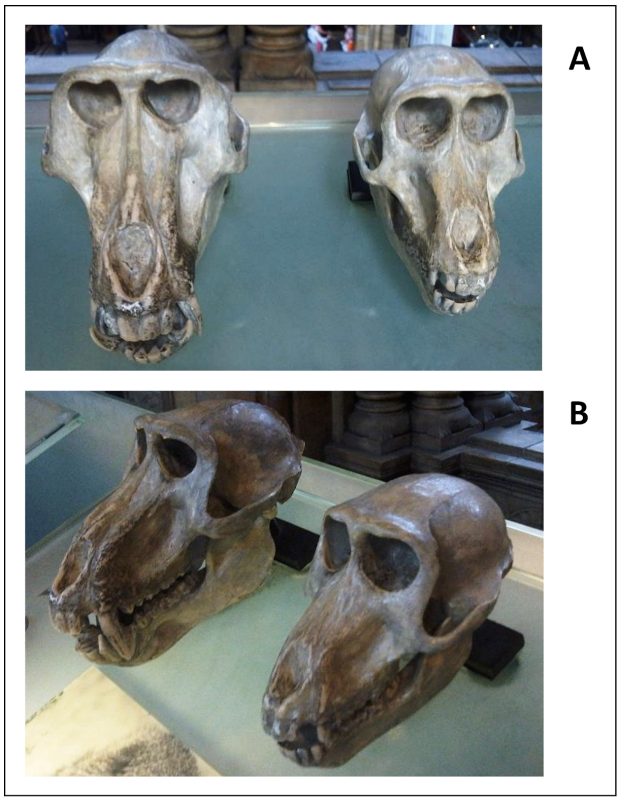


Figure 3. *Papio anubis* (Olive baboon) adult male (left) and female (right) museum skull casts in **A** - anterior and **B** - oblique lateral views.

3D Tooth Model Instructions:

MorphoSource, Duke University (https://www.morphosource.org/Browse/Index)

To identify morphological features of the upper second molars (M2) of chimpanzees and baboons, we recommend that you access the following specimens on MorphoSource, an NSF-funded 3D scan data share website.

Specimens:

AMNH 187371 - *Papio anubis* (anubis baboon)

3D Tooth Model: https://www.morphosource.org/Detail/MediaDetail/Show/media_id/11821

Source: https://www.morphosource.org/Detail/MediaDetail/Show/media_id/11821

AMNH 90293 - *Pan troglodytes* (chimpanzee)

3D Tooth Model:

https://www.morphosource.org/Detail/MediaDetail/Show/media_id/11549

Source: https://www.morphosource.org/Detail/MediaDetail/Show/media_id/11821

Instructions:

1. Open the link for the 3D Tooth Model.
2. If it has loaded but the image does not appear on the screen, click out of the current tab you are working in (e.g., open a new tab) and then click back to MorphoSource. Sometimes, this allows the site to “refresh.”
3. When you see the specimen, note that the base of the tooth is empty and the visible features are on the occlusal surface.
4. You can zoom in on the 3D image for a better look at the features.
5. You can also rotate the specimen in any direction.

We recommend, if possible, that you open the baboon specimen in one tab and the chimpanzee in another tab. That way, you can move back-and-forth between the teeth to more easily note features.

Supplemental E-Material

Supplemental E-Material 1: Extant Primate Skulls

3D Primate Collection - Human Origins, National Museum of Natural History, Smithsonian Institution

https://humanorigins.si.edu/evidence/3d-collection/primates

Instructions:

1. Open website
2. Scroll down page to drop-down menu currently set to <any>
3. Select the common name for the taxon of interest and hit Apply
4. Crania and mandibles are separated for each specimen to allow for better viewing
5. Select an image of a specimen you wish to investigate
6. Ensure Flash is not blocked.
7. You will see the image of the specimen appear in a tan square
8. Manipulate the specimen by moving the mouse in any desired direction
9. Open this page in multiple tabs to easily compare taxa and sexes

Supplemental E-Material 2: Extant Primate Full Skeletons

eSkeletons - Department of Anthropology, University of Texas at Austin

http://www.eskeletons.org/

Instructions:

1. Open website
2. At the top, you will see full skeletons of 13 species of primates
3. Select the species of interest
4. “Skull” will be the default anatomical region
5. Explore different views of the cranium and mandible, including dentition
6. You can select different anatomical regions on the skeleton to the left
7. Open this page in multiple tabs to easily compare taxa

CHAPTER OVERVIEW

9: Early Hominins

Learning Objectives

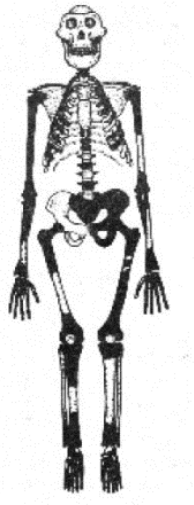
- Recognize skeletal traits associated with bipedal locomotion
- Explain how modern analogs help anthropologists interpret behavior from fossil remains
- Assess australopithecine locomotive behavior using skeletal morphology

Thumbnail: « Lucy » skeleton (AL 288-1) *Australopithecus afarensis*, cast from *Museum national d'histoire naturelle*, Paris. (Cc BY 2.5; 120 via Wikipedia)

9.1: Australopithecine Locomotion

Australopithecine Locomotion

Format: In-person or online



"Lucy" skeleton, *Au. afarensis*

Author: Kristen A. Broehl

Time needed: 20-30 minutes

Supplies Needed

- Casts and/or images (see Supplemental Images) of the following from an anatomically modern human, modern ape, and *Australopithecus afarensis*:
  - Cranium
  - Innominate
  - Sacrum
  - Hand phalanx
  - Scapula
  - Articulated foot (Laetoli Footprints for *Au. afarensis*)
  - Full articulated skeleton
- Colored pencils, pens, or crayons (or ability to color on computer)
- Student worksheet

Readings

- Warren, Kerryn et al. 2019. Chapter 9: Early Hominins. *Explorations*.

Introduction

For this activity, students compare casts and/or photos of *Au. afarensis* to modern humans and apes. Students decide whether each individual trait is more similar to the bipedal human or quadrupedal/brachiating ape and then check the appropriate box and circle the relevant description. Next, students map the traits on an image of *Au. afarensis*, with color-coding by type of locomotion, to interpret the locomotive behavior of australopithecines.

Steps

- Provide students with the casts and images.
- Review or define the relevant skeletal features and other information they may need when making comparisons (see Tips and Suggestions).
- Students can work in groups or independently.
- Review the instructions and have students complete the worksheet.

Review Questions

Which traits associated with bipedalism did you find on the skeleton of *Australopithecus afarensis*?

How does the study of modern humans and apes help anthropologists interpret the behavior of fossil species?

Where on the skeleton did *Australopithecus afarensis* show traits consistent with bipedal and with quadrupedal locomotion? What does this reveal about australopithecine locomotion?

How does *Australopithecus afarensis* demonstrate mosaic evolution?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

Online classes would use the comparative photos (see Supplemental Images) rather than casts. For Part II (mapping traits), students could print, color, and then scan their completed worksheet or just color on the computer.

Tips and Suggestions

1. Most of the features are available from the casts of disarticulated Lucy.
2. I recommend using the images of the scapula/glenoid fossa for both in-person and online classes because the fragment of scapula from Lucy is difficult for students to orient for comparisons.
3. When using casts to compare curvature of the hand phalanges, it is easiest to place the proximal ends flat on a table (see Supplemental Images).

References

Warren, Kerryn, Lindsay Hunter, Navashni Naidoo, Silindokuhle Mavuso, Kimberleigh Tommy, Rosa Moll, and Nomawethu Hlazo. 2019. “Chapter 9: Early Hominins.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Australopithecine Locomotion Worksheet

Part I

In this activity, you will be examining casts and/or images of *Australopithecus afarensis* and the Laetoli Footprints (fossilized footprints associated with *Au. afarensis*). For each trait below:

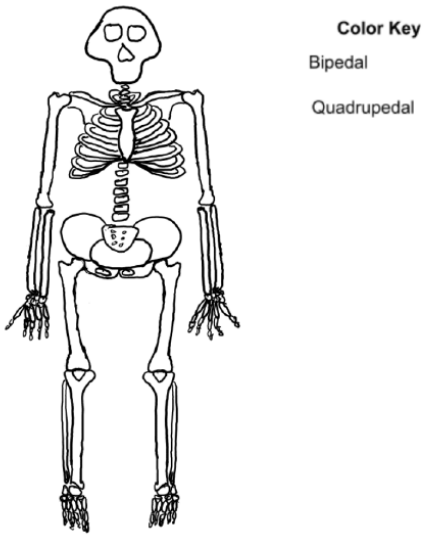
1. Compare the morphology of *Au. afarensis* with the modern human and ape. When assessing traits of the foot, use the Laetoli Footprints as a proxy for *Au. afarensis* foot.
2. Decide whether each trait is more similar to the bipedal human or the quadrupedal/ brachiating ape and mark the appropriate box.
3. Circle the appropriate description of the skeletal element or feature for *Au. afarensis*.

	Bipedal Trait	Quadrupedal Trait	Description (circle)
Foramen magnum position	•	•	Inferior vs. Posterior
Innominate shape	•	•	Short/wide vs. Long/tall
Sacrum shape	•	•	Short/wide vs. Long/tall
Curvature of hand phalanges	•	•	Slight vs. Pronounced
Glenoid fossa location	•	•	Lateral vs. Cranial
Shape of rib cage	•	•	Barrel vs. Funnel
Angulation at knee	•	•	Valgus knee vs. Straight
Relative length of forelimbs	•	•	Short vs. Long
Length of toes relative to foot	•	•	Short vs. Long
Width of heel	•	•	Wide vs. Narrow
Arched foot	•	•	Arched vs. Flat
Big toe divergent vs. convergent	•	•	Mostly convergent vs. Mostly divergent

Part I

Below is a drawing of an australopithecine skeleton. On the skeleton, you will be mapping the distribution of locomotive traits.

1. Pick one color to represent bipedal indicators and a different color to represent quadrupedal/brachiating indicators. Color the "Color Key" accordingly.
2. For each trait listed on the previous page, color over the regions of the skeleton in the color corresponding to whether it is more similar to bipeds or quadrupeds. (For the foramen magnum, you can color beneath the skull since it is not visible in the drawing).
3. After mapping each trait, answer the question below.



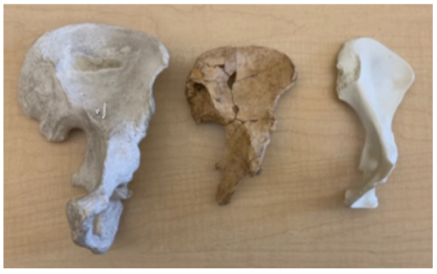
How are bipedal and quadrupedal traits distributed on the skeleton of *Australopithecus afarensis* and what does that tell you about australopithecine locomotion/behavior?

Supplemental Images

The images below show comparisons between an anatomically modern human, *Australopithecus afarensis*, and a modern ape for each trait. Unless otherwise noted, images show the **human** elements on the **left**, ***Au. afarensis*** in the **middle**, and the **ape** on the **right**.

Cranium

Trait: foramen magnum position



Innominate

Trait: innominate shape

Sacrum

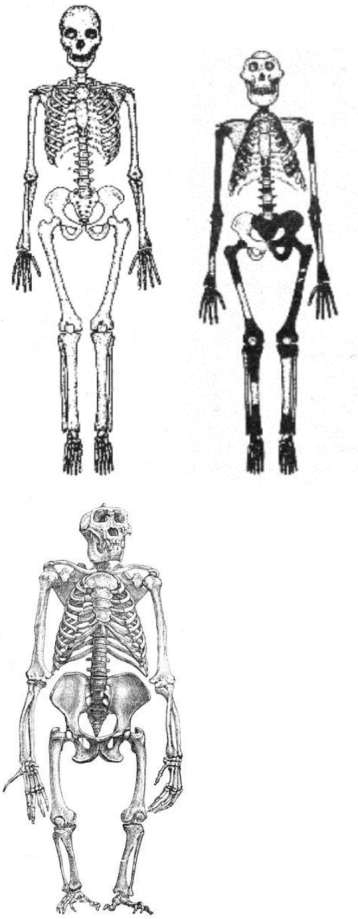
Trait: sacrum shape

Hand phalanx

Trait: curvature of hand phalanges

Scapula

Trait: glenoid fossa location



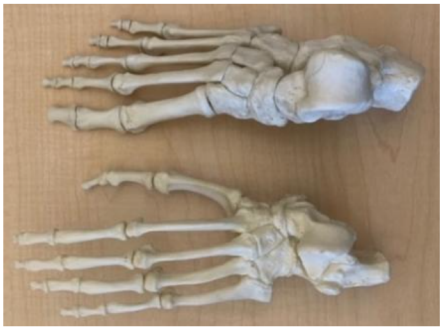
Articulated Skeleton

Traits: shape of rib cage, angulation at knee, relative length of forelimbs

Laetoli Footprints

Au. afarensis

Traits: width of heel, length of toes relative to foot, arched foot, big toe divergent vs. convergent



Foot

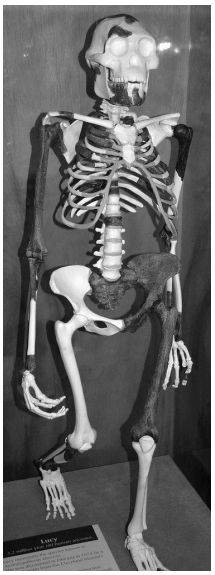
Human (top) and ape (bottom)

Traits: width of heel, length of toes relative to foot, arched foot, big toe divergent vs. convergent

9.2: Tactile Evolution

Tactile Evolution

Format: In-person



of *Australopithecus afarensis* (Lucy)A depiction of the lower skeletal anatomy

Authors: Katherine E. Brent and Sydney Quinn Chizmeshya

Time needed: 5-10 minutes per element

Learning Objectives

- Visualize and explain morphological changes related to bipedalism
- Use kinesthetic learning to retain information about skeletal features of bipedalism

Supplies Needed

- Element reference sheets (included)
- Modeling clay

Readings

- Yoshida-Levine, Bonnie. 2019. Chapter 9: Early Hominins. *Explorations.*

Introduction

Modern humans are obligate bipeds: we are designed to always walk upright on two legs. Human ancestors, however, were not all obligate bipeds-- many were adapted for arboreal activities as well. In this activity, we will examine which skeletal changes are present in non-obligate and obligate bipeds, and we will use chimpanzees and modern humans as examples. Notably, there are also soft tissue changes that come with a shift to obligate bipedalism. Since the primary source of evidence for biological anthropologists is skeletonized and fossilized remains, we will be focusing on skeletal changes.

Specifically, students will construct models of non-obligate biped skeletal elements using modeling clay and then ‘evolve’ them into obligate skeletal elements. This activity allows students to develop a tactile sense of the skeletal differences and changes between non-obligate bipeds and obligate bipeds.

Steps

- Students may work in groups or individually. Each group or individual receives one ball of clay per skeletal element, the Element Reference Sheet(s), and Student Worksheet.
- Students use the clay to construct the element as it appears in a non-obligate biped, using the Element Reference Sheet for guidance. For this activity, a chimpanzee will be used, but other non-obligate bipeds may be used instead.

- After constructing the non-obligate biped element, students make appropriate changes in order to transform the element into one resembling that of an obligate biped. Students may add, remove, or sculpt the clay to make changes but they must not destroy the prior element. In this case, the modern *Homo sapiens* will be used as a model, although a different obligate biped may be used instead.
- Students should understand that the model non-obligate biped (i.e. modern chimpanzees) are NOT an ancestor of modern humans. The models are only used to display general characteristics of non-obligate bipeds. The line illustrations are simplified to facilitate easier modeling.

Review Questions

- Discuss the challenges you encountered in transforming the non-obligate biped model into an obligate biped model.
- Which morphological or skeletal changes seemed most significant and why?
- The proportionately smaller upper limbs, and S instead of C curved spines in obligate bipeds can be difficult to model. How did you address this? Why are these features important for obligate bipeds?

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Students could construct the models at home, using clay, and then photograph and upload into the learning management system's discussion board. Students could then discuss each other's models and the challenges they encountered.

Tips and Suggestions

After the activity, encourage students to read about regional skeletal anatomical variation between obligate and non-obligate bipeds on p. 329 of *Explorations*—this will help students to connect the kinesthetic knowledge that they have developed to specific anthropological terminology.

For Further Exploration

The Smithsonian National Museum of Natural History's *Human Family Tree:*

https://humanorigins.si.edu/evidence/human-family-tree

References

Yoshida-Levine, Bonnie. 2019. "Chapter 9: Early Hominins." *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Australopithecus afarensis fossil hominid (Lucy skeleton) (Hadar Formation, Pliocene, 3.2 Ma; Hadar area, Afar Triangle, northern Ethiopia, eastern Africa) 1 by James St. John is licensed under CC BY 2.0.

All reference sheet images are drawn by Katherine E. Brent and licensed under CC BY-NC 4.0.

Tactile Evolution Worksheet

Name_____ Date_____

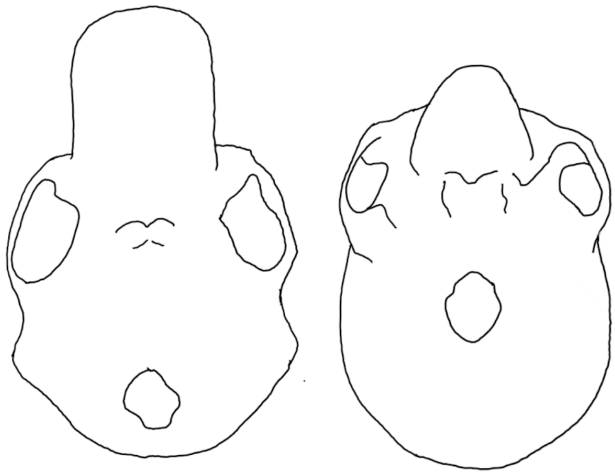
1. List the skeletal elements that you modeled using clay.

2. For each element, describe how you transformed it from the non-obligate biped form into the obligate biped form.

3. For each element, what was one challenge you encountered in transforming the element?

4. For each element, what was the most significant change needed to achieve the obligate biped form?

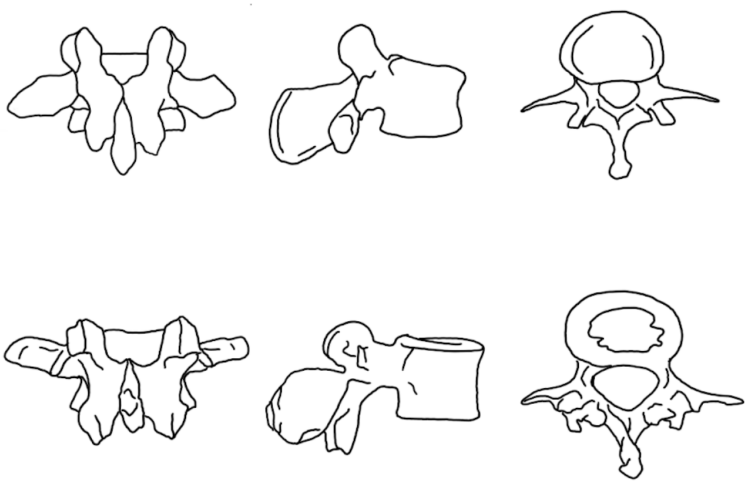
Element Reference Sheet: Cranium



Left: Non-obligate biped (chimpanzee)

Right: Obligate biped (modern human)

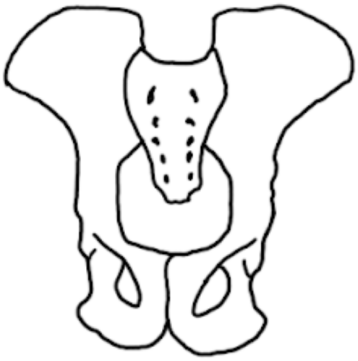
Element Reference Sheet: Lumbar Vertebrae

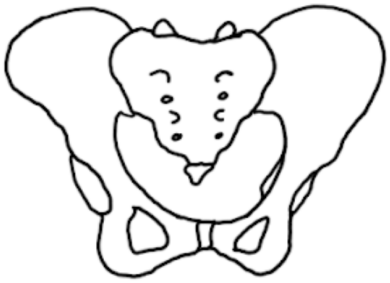


Top: Non-obligate biped (chimpanzee)

Bottom: Obligate biped (modern human)

Element Reference Sheet: Pelvis

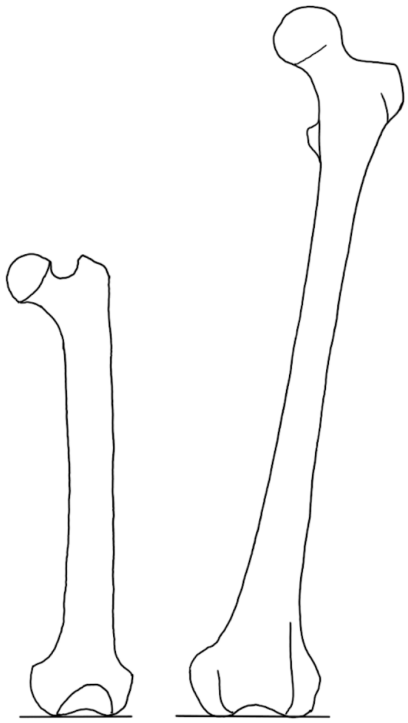




Top: Non-obligate biped (chimpanzee)

Bottom: Obligate biped (modern human)

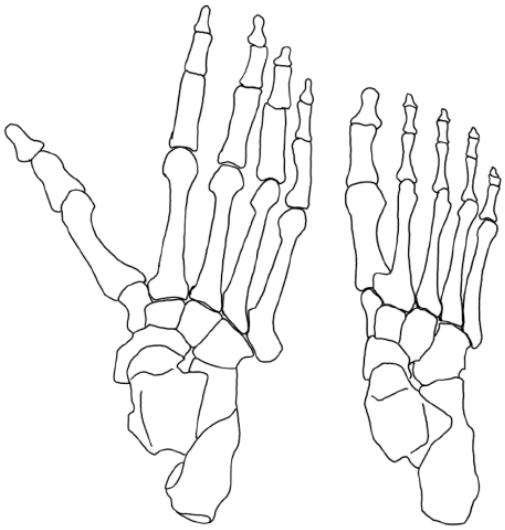
Element Reference Sheet: Femur



Left: Non-obligate biped (chimpanzee)

Right: Obligate biped (modern human)

Element Reference Sheet: Foot



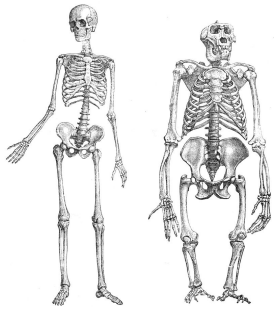
Left: Non-obligate biped (chimpanzee)

Right: Obligate biped (modern human)

9.3: Fossil Hominins

Fossil Hominins

Format: In-person or online



Compared to gorillas (right) and other apes, humans (left) have highly specialized adaptations to facilitate bipedal locomotion.

Author: Rebecca Frank

Source: “Activity 14.” 2019. Frank, Rebecca, Brian Pierson, Philip Stein. *LAVC Anthro 111 Lab Manual. 7th Edition*.

Time needed: 60-90 minutes

Learning Objectives

- Identify hominin fossil features
- Compare ape, *Ardipithecus*, Australopithecines, and modern human anatomy
- Use fossil features to understand the emergence of bipedalism

Supplies Needed

- Skull casts of ape, *Ardipithecus*, gracile and robust Australopithecines, and modern *Homo sapiens*
- Pelvis and foot casts of ape, gracile Australopithecine, and modern *Homo sapiens*
- Student worksheet (below)

Readings

- Warren, Kerryn, et al. 2019. “Chapter 9: Early Hominins.” *Explorations.*

Introduction

This lab examines hominin fossils using a series of casts, reproductions, and photographs. This is an application of what students have already learned about human and primate anatomy in prior weeks of a typical Biological Anthropology lab course. This lab includes three exercises in which students examine and measure fossil casts. It is assumed that students have a good working knowledge of anatomy from the textbook, lectures, and/or previous exercises.

Steps

-
- Before class, the instructor should organize the fossil casts for students to analyze individually or in groups.
- For Exercise 1, students will need access to skull casts of an ape, *Ardipithecus*, a gracile *Australopithecus* (such as *Au. africanus* or *Au. afarensis*), and a robust Australopithecine (*Paranthropus)*.
- For Exercise 2, students will need access to pelvis casts of an ape, *Au. afarensis* (or another gracile Australopithecine), and a modern human, as well as foot casts of an ape, *Ardipithecus*, and a modern human.
- For Exercise 3, students will need access to a *Paranthropus* fossil skull cast.
- Students will analyze fossils, complete charts, and answer questions on the worksheet.

Review Questions

- Compare *Au. africanus* and *Au. afarensis* to an ape and modern human. Why are these species considered to be hominins rather than apes?
- Name three species of robust Australopithecines. Identify their most significant shared features.

- Does the Australopithecine pelvis resemble most closely a hominin or an ape?

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Much of the data students will collect for the worksheets is descriptive. For online courses, using photographs and online 3D rotation images, students can compare the skulls and pelvic girdles of the species. Many resources are free to post in online course management systems. Additional options could be available with subscriptions or other licensing agreements. See for example: https://africanfossils.org/, http://efossils.org/, https://sketchfab.com/, https://3d.si.edu/collections/hominin-fossils

References

Frank, Rebecca. 2019. “Activity 14: The Hominin Fossils: Australopithecines.” In *LAVC Anthro 111 Lab Manual*, 7th Edition, edited by Frank, Rebecca, Brian Pierson, and Philip Stein.

Warren, Kerryn, Lindsay Hunter, Navashni Naidoo, Silindokuhle Mavuso, Kimberleigh Tommy, Rosa Moll, Nomawethu Hlazo. 2019. “Chapter 9: Early Hominins.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Skeleton of human (1) and gorilla (2), unnaturally sketched by unknown from Brehms Tierleben, Small Edition 1927 is in the public domain.

Sobotta 1909 fig.41 - The skull, inferior view - No labels by Johannes Sobotta is in the public domain. This item has been modified (arrows added).

Sobotta 1909 fig.40 - The skull, lateral view - No labels by Johannes Sobotta is in the public domain. This item has been modified (arrows added).

Australopithecine Worksheet

Instructions

In this lab, you will compare sets of fossil casts and record your comparisons on a chart. The term *specimen* in the chart refers to the specific fossil or primate species being studied. The name of the species is filled in at the head of the column. Individual fossil specimens are usually identified by an abbreviation indicating the name of the site from which the fossil comes and a number given to each fossil from the site. For example, OH 5 stands for the fifth hominin fossil from Olduvai Gorge: Olduvai Hominin 5. The fossil casts for your class may or may not be labeled this way.

The early hominins include a diverse group of African fossils that include the genera *Sahelanthropus*, *Orrorin*, *Ardipithecus*, *Australopithecus*, and *Paranthropus.* The many species represented by these genera lived from about 7 million years ago (mya) to almost 1.0 mya. Early hominin fossils are found in South Africa, East Africa, and Chad (north central Africa). None are found outside of Africa.

- The early hominins are those that show many transitional features between the apes and later hominins. They include *Sahelanthropus tchadensis*, *Orrorin tugenensis*, *Ardipithecus ramidus*, and *Ardipithecus kadabba*. These species lived between 6.8 and 4.4 mya.
- Three of the well known gracile Australopithecines are *Australopithecus anamensis* and *Australopithecus afarensis* from East Africa, and *Australopithecus africanus* from South Africa. They lived between 4.2 and 2.1 mya.
- Many paleoanthropologists classify the robust Australopithecines in the genus *Paranthropus.* There are three known species: *Paranthropus aethiopicus* and *Paranthropus boisei* from East Africa and *Paranthropus robustus* from South Africa. They lived between 2.7 and 1.0 mya and were contemporary with the genus *Homo.*

Exercise 1. The Gracile Australopithecines

While *Sahelanthropus*, *Orrorin*, and *Ardipithecus* are considered transitional genera, the gracile Australopithecines (*Australopithecus africanus* and *Australopithecus afarensis*) are clearly hominins. In Exercise 1, you will look closely at some of

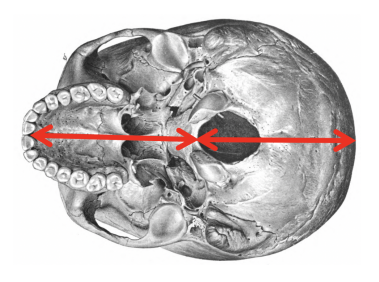
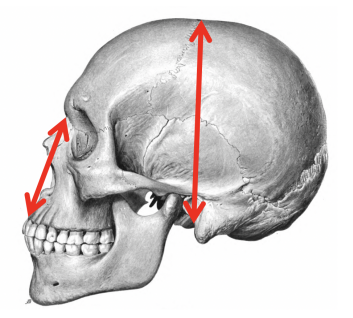
these species.

Your instructor will tell you which four species' skulls to compare in the table on the worksheet. There are four ways to fill in a cell, depending on how the statement of feature is phrased.

1. Present or absent: When a feature is either there or not, you can use a + for present and – for absent. For example, "presence of sagittal crest" can be answered + or –.
2. Describe: When you are asked to describe a feature, do so with a few words or short phrase. For example, "shape of dental arcade" can be answered "U-shaped."
3. Compare: When you are asked to compare, you need to ask "compare to what?" If there are three skulls being compared, you might say X and Y are smaller than Z. Or X is smaller than Y and Y is larger than Z.
4. Measure: In several tables you are asked to calculate an index. Measure for these boxes only. Write down both your measurements and the index. Diagrams showing how to take the measurements and calculate the indexes are shown below.

We will measure and calculate the Condylar Index and the Facial Index. The Facial Index assesses the relative size of the face (and teeth and chewing features) vs. the size of the brain.

Record your measurements and comparisons to complete "Exercise 1" on the worksheet.

Condylar Index = (basion to opisthocranion) / (basion to prosthion) x 100	**Facial Index:** [Upper Facial Height] Nasion (n) to prosthion (pr) / [Cranial height] basion (ba) to bregma (b) x 100
	

Type	Ape	*Ardipithecus*	Gracile Australopithecine	"Robust" Australopithecine *Paranthropus*
Species name & Specimen ID				
Location of occipital condyles on base of skull				
Condylar Index = (Ba to Op / Ba to Pr) x 100				
Position of maximum skull breadth when viewed from back				
Presence and degree of postorbital constriction in superior view				
Size of neurocranium relative to size of facial skeleton as seen in the lateral view				
Facial Index = (Upper Facial Height / Cranial Height) x 100				
Degree of prognathism as seen in the lateral view				

Presence and degree of development of supraorbital torus				
Robustness of zygomatic arch				
Presence of a sagittal crest				
Presence of a mental eminence				
Relative size of incisors vs. molars (M > or < or = I)				
Size of canines to other teeth (C > or =)				
In mandible: presence of diastema and sectorial premolar				

Exercise 2. Bipedal Adaptations: Pelvis and Foot

Our earliest hominin ancestors were essentially bipedal apes. The first hominins walked on two legs but had small brains and retained adaptations for climbing trees. When a new fossil is discovered, paleoanthropologists spend a great deal of time and care studying the remains to determine the locomotor pattern for that species. It is not a straightforward process and claims that recent discoveries such as *Sahelanthropus, Orrorin, and Ardipithecus* species are bipedal have generated a lot of discussion.

In this exercise we will examine the pelves of an ape, *Au. afarensis*, and a modern human, and consider changes that occurred as our ancestors evolved from quadrupeds to bipeds. We will also look at, and compare, the feet of an ape, *Ardipithecus*, and modern human.

The pelvis underwent significant changes as part of this process, but other parts of the postcranial skeleton were also affected by selection for bipedality**.** It is also important to remember that bipedal locomotion in the earlier hominins was not identical to the way we now move. This will be apparent as we compare pelves today. You may want to review the textbook descriptions of the modern human pelvis and ape pelvis, as well as descriptions of Australopithecine pelvis and feet.

Answer the questions and record your answers in the chart.

Compare the shape of the pelvis between humans, ape, and *Au. afarensis*. How are they different? Discuss how features in the two hominins enabled bipedal walking.

Compare the shape of the humans, ape, and *Ardipithecus* foot. How are they different? How do the features in the two hominins enable bipedal walking?

What other parts of the skeleton (besides the pelvis) have been reshaped for bipedal locomotion and might be useful in identifying a fossil as being hominin? Describe changes that have occurred.

	Ape	*Au. afarensis*	Modern human
Specimen label			
General shape of pelvis			
Relative position of sacroiliac and acetabular joints			
Position of iliac blade relative to spine			
Shape of pelvic inlet			
Breadth / Height of pelvic inlet x 100 = **Pelvic Inlet Index**			
(Ilium Breadth / Ilium Height) x 100 = **Ilium Index**			
Relative size of anterior inferior iliac spine			
Relative length of ischium bone			

How are modern humans and *Au. afarensis* similar? How are they different? What inferences can you make about bipedality in *Au. afarensis*?

Exercise 3. *Paranthropus "Robust" Australopithecines*

Between three and one million years ago, some hominins begin to exhibit larger posterior dentition, changes in dental enamel, and cranial evidence that suggest variation in dietary strategies among hominins. The large-molared hominins can be referred to as "robust" Australopithecines (in contrast to "gracile" Australopithecines like *Au. africanus)*, though many researchers have placed them into a separate genus: *Paranthropus*. Some have speculated that they developed specializations in the jaws and teeth that allowed for processing tough, fibrous material such as grasses and hard seeds. The relationship between the two groups is unknown, but both have been found in the same sites, although at different time periods.

Paleoanthropologists recognize three species of robust Australopithecines or *Paranthropus:*

- *Paranthropus aethiopicus* is known from East Africa. It is the oldest of the group, dated at 2.7 - 2.3 mya, and is somewhat more primitive than later forms. It was discovered in 1984.
- *Paranthropus robustus* is a species that existed in South Africa between 2.3 and 1 mya. It was first discovered between 1936 and 1939 by Robert Broom.
- *Paranthropus boisei* is a species that existed in East Africa between 2.4 and 1.4 mya. It has larger posterior teeth and more developed jaw musculature than those living in the south. It was first discovered by Mary Leakey at Olduvai Gorge in 1959.

Examine the *Paranthropus* fossil casts and then answer these questions.

List three anatomical features suggest that *Paranthropus* ate a diet of tough, fibrous plant material.

In contrast, what might have been the diet of gracile Australopithecine species? How do you know?

CHAPTER OVERVIEW

10: Early Members of the Genus Homo

Learning Objectives

- Compare/contrast the diets of early hominins
- Understand the relationship among tool traditions, food processing, and diet

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10.1: Hominin Dinner Party

Hominin Dinner Party

Format: In-person

An artistic reconstruction of *Australopithecus africanus* by John Gurche.

Author: Kristina Killgrove

Time needed: 45-60 minutes

Supplies Needed

- Food supplies related to the categories below

Readings

- Yoshida-Levine, Bonnie. 2019. Chapter 9: Early Hominins. *Explorations.*
- Chan, Keith. 2019. Chapter 10: Early Members of the Genus Homo. *Explorations.*

Introduction

To illustrate hominin diets and the first use of tools in food processing, we are holding a hominin potluck dinner party. Invited to the party, which will occur over a 3-million year span, are: early australopiths (Au. anamensis and Au. afarensis), robust australopiths (Au. robustus and Au. aethiopicus), gracile australopiths (Au. garhi and Au. africanus), and early Homos (H. habilis and H. rudolfensis). As the party is a potluck, each group must bring a dish. The host has allocated dishes based on the primary component of each group's diet, and each group can only use the tools and materials that were historically available to them.

Steps

- Instructors read the introduction (above) and hand out the Student Worksheet.
- Students work individually or in groups to answer the questions.

Conclusion or Review Questions

- As a class, students discuss the questions on the Student Worksheet (below).

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

References

Chan, Keith. 2019. "Chapter 10: Early Members of the Genus Homo." *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Yoshida-Levine, Bonnie. 2019. "Chapter 9: Early Hominins." *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Australopithecus africanus. Reconstruction based on STS 5 by John Gurche

by Smithsonian [exhibit: Reconstructed Faces, What does it mean to be human?] is copyrighted and used for educational and noncommercial purposes as outlined by the Smithsonian.

Hominin Dinner Party Worksheet

NAME(S): DATE:

At the potluck, each group brings a dish, based on the primary component of their diet:

- Early Australopiths (Au. anamensis and Au. afarensis) – Dessert. As their diet was largely frugivorous, complemented by nuts and seeds, this group needs to create a dessert made out of fruit and nuts.
- Gracile Australopiths (Au. garhi and Au. africanus)– Vegetables. These species ate a wide variety of foods, including vegetables. This group therefore needs to create a vegetable dish out of the available ingredients.
- Robust Australopiths (Au. robustus and Au. aethiopicus) – Starch. The robusts ate a lot of fruit but also a lot of hard tubers and root vegetables. This group is therefore creating a starchy, carb-heavy dish, much like the modern potato salad.
- Early Homo (H. habilis and H. rudolfensis)– Meat and Marrow. While there is evidence that earlier species also scavenged meat, we are fairly confident the early Homos were comfortable processing and eating meat. This group will therefore butcher an animal and extract marrow from bones.

All food must be prepared with the stone tools at each group's disposal. All group members take an active role in food preparation, as hominin species likely had no sexual division of labor and everyone had to pull his/her own weight. If there are leftover ingredients, you may share among groups to make your dish more appetizing!

To answer these questions, you will need to review your lecture notes, *Explorations* chapters 9 and 10, and do additional research.

QUESTIONS

1. For each group: List the kinds of tools they had available or were able to create.

Species	Main food source	Tools/Materials
Early Australopiths	Fruit, nuts, seeds	
Gracile Australopiths	Vegetables	
Robust Australopiths	Fruit, tubers, root vegetables	
Early Homo	Meat, marrow	

2. Before you started this exercise: How difficult or easy did you think it would be to process the foodstuffs you were given with the stone tools associated with each group? Which group(s) had the easiest or most difficult time using the tools and why?
3. What dish did you make? Write out an approximate recipe including amounts (e.g. two pears) and instructions, including tool use (e.g. using chopper; bash open the coconut).
4. What was in the other dishes? Whose dish looked the tastiest and why? Which dish would you prefer to eat as a habiline? Would your preference change if you evolved and were able to cook your food? How would it change?
5. Do further research about the diet of each group, using your textbook or the internet. How closely do you think your dish approximated what the hominins would have eaten? In what ways could you make the dish more accurately match the hominins' diets?
6. How does each species diet relate to their skeletal and morphological features that you've learned about?

10.2: Early Homo Lab

Early Homo Virtual Lab

Format: In Person or Online

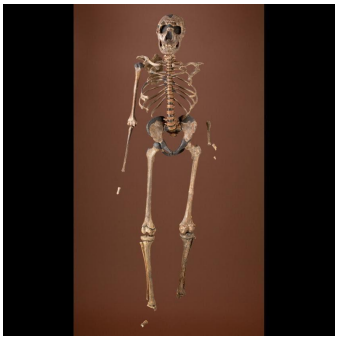


Figure 1: Skeleton of a young male *Homo erectus* known as “Nariokotome Boy

Author: Beth Shook

Modified from labs by Henry M. McHenry, University of California, Davis.

Time needed: 50 - 60 minutes

Learning Objectives

- Examine cranial and postcranial differences among *Australopithecus africanus*, *Homo habilis*, and *Homo erectus*
- Compare and contrast the logics of “lumping” and “splitting”
- Describe variation within *Homo erectus*
- Identify early *Homo* tool traditions

Supplies Needed

- Access to the internet to explore (provided) links to web-based 3D models of hominin fossils and tools or casts of fossil hominins

Readings

-

Introduction

In this lab students examine fossils of the earliest species of the genus *Homo*: *Homo habilis* and *Homo erectus*. Both species overlap with the end of the Australopithecines chronologically, with *Homo erectus* outliving any of the rest. Debate surrounds the classification of both species, primarily about whether they should be lumped into one species each, or split into two. For example, all *Homo habilis* could be lumped as *Homo habilis*, or split into *Homo habilis* and *Homo rudolfensis*.

By approximately 2.5 million years ago (mya), the earliest members of the genus *Homo* (*Homo habilis*) had developed, and by 1.6 mya *Homo erectus* had spread throughout Africa and Asia. To understand the big picture - the key changes with the advent and spread of early *Homo* - students will examine and record the differences between *Australopithecus africanus*, *Homo habilis*, and *Homo erectus*.

In this activity students utilize links to 3D models of several hominin species and early hominin tools (available at sketchfab.com, efossils.org, and eskeletons.org) to make observations about and compare them. Students will then complete data tables and answer questions about these models.

Steps

1. **Trends of the Genus *Homo*:** Examine 3D scans of fossils from different *Homo* species; complete the chart and answer questions on the worksheet to identify major trends across the genus.
2. **Lumping and Splitting: *Homo habilis* v. *Homo rudolfensis*:** Compare the type specimens for *Homo habilis* and (possible) *Homo rudolfensis*; complete the chart and answer questions.

3. ***Homo erectus* Over Space and Time:** Examine *Homo erectus* fossils from four different sites; complete the chart and answer questions.
4. **Changing Postcrania:** Compare postcrania features of *Au. afarensis*, *H. habilis*, *H. erectus*, and *H. sapiens.*
5. **Developing Tools:** Record observations about Lomekwian, Oldowan, and Acheulean tool traditions.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

References

efossils. 2021. 3D fossils from efossils.org at the University of Texas at Austin.

eskeletons. 2021. 3D fossils. eskeletons.org at the University of Texas at Austin.

Sketch Fab. 2021. 3D fossils from sketchfab.org.

Yoshida-Levine, Bonnie. 2019. "Chapter 10: Early Homo." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Figure 1. KNM-WT 15000 Turkana Boy Skeleton by Smithsonian [exhibit: Human Evolution Evidence, Human Fossils, Fossils, KNM-WT 15000] is copyrighted and used for educational and non-commercial purposes as outlined by the Smithsonian.

Figure 2. Homo erectus site map original to Explorations: An Open Invitation to Biological Anthropology by Chelsea Barron at GeoPlace, California State University, Chico is under a CC BY-NC 4.0 License.

Early Homo Virtual Lab Worksheet

In the table below, each species' name contains links to 3D scans of fossils from Sketchfab. If possible, you are encouraged to open two or more of these links at the same time (in different windows) to allow you to look at them at the same time and compare them. You can record your observations using comparative terms such as "largest", "smallest", "most prognathic", in addition to specific descriptive terms like "parabolic" or "U-shaped" that were presented in the chapter.

	Au. africanus skull *Au. africanus* mandible	*H. habilis*	Early *H. erectus* skull *H. erectus* mandible	*H. sapiens skull* *H. sapiens mandible*
Cranial capacity	400-500 cc	510-775 cc	650-1100 cc	Avg. 1350 cc
Size and shape of brow ridges				
Extent of prognathism (jutting out of lower face)				
Size of molar and premolar chewing surface				
Shape of dental arcade				
Geographic location	South Africa	South and East Africa	Africa and Asia	All over the world

Based on your observations, what are two major trends that continue across the genus *Homo?*

The genus *Homo* suggests reliance on tools as well as dietary and behavioral flexibility. The earliest fossils that belong to this genus appear between 2.8 and 2.5 mya, and they extend to about 1.7 mya. This fossil collection, however, does vary significantly in facial and cranial size, suggesting to some they should be "split" into two separate species. Other paleontologists prefer to "lump" similar fossils explaining the diversity as natural variation or differences between the sexes.

Compare the type specimens for *Homo habilis* and (possible) *Homo rudolfensis.* What differences do you observe? Given what you saw for species differences in previous fossil comparisons, do you think there are enough differences to consider them two different species?

	KNM-ER 1813 *Homo habilis*	KNM-ER 1470 Possible *Homo rudolfensis*
Cranial capacity	510 cc	775 cc
Size and shape of brow ridges		
Face size		
Size of molar and premolar chewing surface		
Posterior (back) view of the braincase		
Upper limbs	Longer (primitive)	Shorter (more derived)

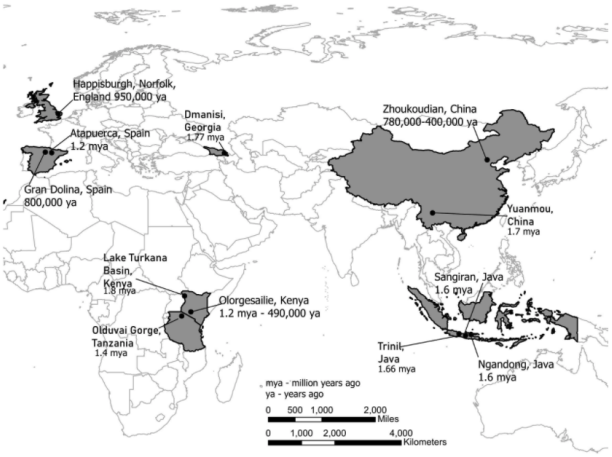
Consider other features: what similarities do you see between the two fossils?

Based on your observations, do you think that *H. habilis* should be one species or split into two? Why or why not?

3: *Homo erectus* Over Space and Time

Homo erectus was the first hominin that we know left Africa. It quickly spread across Asia, reaching the island of Java by ~1.6 or 1.7 mya. The spreading population existed for over one million years, diversifying over time and space. Complete the table below comparing specific fossil examples of *Homo erectus.*

	H. erectus Lake Turkana Basin, 1.8 mya	*H. erectus* Dmanisi, Georgia, 1.7 mya	*H. erectus* Java, 1.6 mya (skullcap)	*H. erectus* Zhoukoudian, China, 780 - 400 kya
Cranial capacity	880 cc	546-775 cc	Est. 900 cc	~1000 - 1225 cc
Cranial bones	Thinner	Thinner	Thick	Thick
Brow ridges			One large single brow, pronounced	
Braincase shape			Long and low	
Other traits- Please note at least two observations			NA	



Map illustrating the distribution of *Homo erectus* (from *Explorations* Chapter 10).

4: Changing Postcrania

While both Australopithecines and early *Homo* were obligate bipeds, there are some modifications that occured over the past four million years. Compare and contrast *Au. afarensis*, *H. habilis*, *H. erectus*, and *H. sapiens.* In each cell of the table below, note any unique or changing characteristics that you observe. Note: The fossils for this comparison are from the efossils and eskeletons website.

	Au. afarensis	*H. habilis*	*H. erectus*	*H. sapiens*
Femur				
Os Coxa (Pelvis)		NA		

Overall, what is one of the major trends in hominin postcrania that occurs across the genus *Homo*?

5: Developing Tools

Follow the links below to view 3D models of Lomekwian, Oldowan, and Acheulean tools. In the table below, describe what you observe about each tool type.

	Lomekwian Tool Example (3.3 mya)	(2.5 - 1.6 mya)	Acheulean Tool Example (~1.5 mya to 200 kya)
Describe key distinguishing features of the three tools			
Identify what these tools could have been used for			
The genus/species it is most often associated with	*Australopithecus*	*Homo habilis*	*Homo erectus*

CHAPTER OVERVIEW

11: Archaic Homo

Learning Objectives

- Summarize anatomical and behavioral developments among hominin groups.
- Identify common trends in hominin evolution.
- Specify the best indicators of specific hominin species.

11.1: Hominin Review- Evolutionary Trends

Hominin Review: Evolutionary Trends

Format: In-person or online

Artistic reconstruction of a *Paranthropus boisei*, male, by John Gurche.

Author: Perash, Rose L., and Broehl, Kristen A.

Modified from labs by Henry M. McHenry, University of California, Davis, and Beth Shook, California State University Chico.

Time needed: 30 minutes

Supplies Needed

- Worksheet (provided)

Readings

-
- Yoshida-Levine, Bonnie. Chapter 10: Early Members of the Genus Homo. *Explorations.*
- Warren, Kerryn, et. al. Chapter 9: Early Hominins. Explorations.

Introduction

This is a review/synthesis of trends in hominin evolution designed for after students have completed *Explorations* chapters 9, 10, and 11. For this activity, students match the descriptions of anatomical changes or behavioral traits with the number that corresponds to the correct hominin species on the phylogenies (one for anatomy and one for behavior/culture).

Steps

1. Summarize anatomical and behavioral developments among hominin groups.
2. Handout the student worksheet and ask students to answer each question, using the phylogeny charts as reference.
3. Upon completion, review the correct answers with the class and summarize.

Tips and Suggestions

This exercise works well as group work. It is often helpful for students to look for the most unique descriptors first (rather than proceed with descriptors in the order listed). For example, “mental eminence” is often a straightforward one that can help students get started.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

References

Paskey, Amanda Wolcott; Beasley Cisneros, AnnMarie. 2019. “Chapter 11: Archaic Homo”. In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Warren, Kerryn, et. al. 2019. “Chapter 9: Early Hominins. Explorations” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological

Association. http://explorations.americananthro.org/

Yoshida-Levine, Bonnie. 2019. “Chapter 10: Early Members of the Genus Homo”. In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Paranthropus boisei, male. Reconstruction based on OH 5 and KNM-ER 406 by John Gurche by Smithsonian [exhibit: Reconstructed Faces, What does it mean to be human?] is copyrighted and used for educational and noncommercial purposes as outlined by the Smithsonian.

Hominin Review: Evolutionary Trends

Step One: Anatomical Developments

Match the following anatomical developments (A-J) with the number where they occur on the Hominin Anatomy Phylogeny (below).

_____ A. decreased prognathism, moderate sized molars, phalanges not curved (derived), Found in South Africa, still relatively small brain (~450cc)

_____ B. canine reduction, lower jaw tooth row shape intermediate between parallel and parabolic, have footprints explicitly displaying bipedal patterns, curved phalanges

_____ C. further brain expansion, decrease in teeth size, decrease in brow ridges, flattening of the face, mental eminence, vertical forehead

_____ D. megadontia complex (huge molars, jaws, and chewing muscles), slight increase in cranial capacity (410-530cc)

_____ E. femur and pelvis indicate capable of bipedalism

_____ F. brain expansion, megadontia reduction, smaller less projecting face, smaller jaws

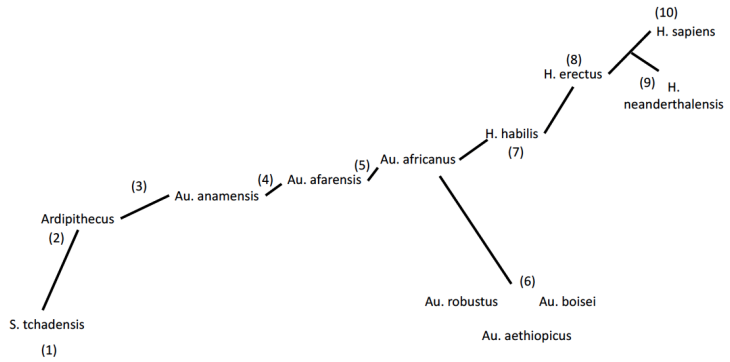
_____ G. occipital bun common, retromolar space, robust postcrania, relatively short limbs

_____ H. further brain expansion, reduction in teeth, face, and jaws, increased brow ridges, increased body size

_____ I. loss of honing complex, obligate bipedalism, curved phalanges (primitive), parallel tooth row shape

_____ J. foramen magnum position indicates likely capable of bipedalism

Hominin Anatomy Phylogeny



Step Two: Behavioral Developments

Match the following behavioral developments (A-G) with the number where they occur on the Hominin Behavior Phylogeny (below).

_____ A. Mixture of arboreal and bipedal lifestyle, as seen in hand and foot anatomy. Likely due to a patchy savannah environment.

_____ B. Traditionally seen as the first hominin to also live outside the African continent. Used stone tools, including handaxes (Acheulean tool tradition).

_____ C. Used stone tools (Mousterian tool tradition). Likely had intentional burials and made symbolic objects. Lived in Europe and the Near East.

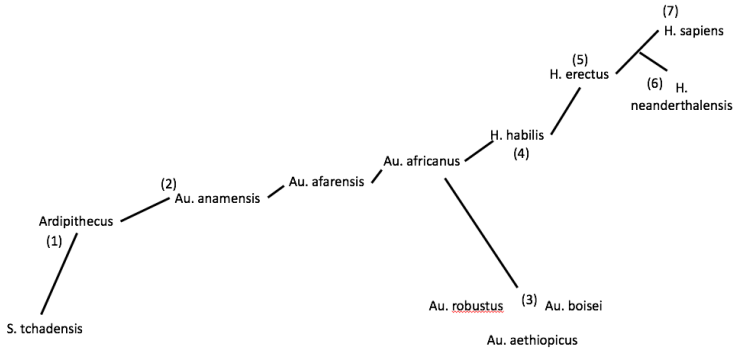
_____ D. Evidence of meat scavenging, but no evidence of stone tools or hunting.

_____ E. Used a variety of tool technologies, including harpoons, barbs, and traps. Lived on all continents.

_____ F. Ate a diet mainly of tough plant foods like nuts, seeds, grasses, and tubers.

_____ G. Traditionally seen as the first users of stone tools (Oldowan tool tradition).

Hominin Behavior Phylogeny



11.2: The Genus Homo

The Genus *Homo* Lab

Format: In-person or online

many classic Neanderthal features. La Ferrassie 1 Neanderthal is representative of

Author: Rebecca Frank

Source: “Activity 15.” 2019. Frank, Rebecca, Brian Pierson, Philip Stein. *LAVC Anthro 111 Lab Manual. 7th Edition*.

Time needed: 60-90 minutes

Learning Objectives

- Compare early *Homo* species to *Au. africanus*
- Compare species of *Homo*
-

Supplies Needed

- Fossil casts of *Au africanus, H. erectus, H. heidelbergensis, H. neanderthalensis, H. sapiens*
- Student worksheet (provided)

Readings

- Yoshida-Levine, Bonnie. 2019. Chapter 10. *Explorations.*
- Paskey, Amanda and AnnMarie Beasley Cisneros. 2019. Chapter 11. *Explorations*

Introduction

The genus *Homo* first appears around 2.5 million years ago in East Africa. By this time all but one *Australopithecus* species has become extinct. *Paranthropus* survives as a contemporary of *Homo* for almost 1.5 million years.

We see a number of trends in this genus, perhaps the most important being the enlargement of the brain, increase in stature, and the elaboration of technology including stone tools. However, the genus is quite variable. There are many species within *Homo* including *Homo habilis*, *Homo rudolfensis*, *Homo erectus*, *Homo heidelbergensis*, *Homo neandertalensis*, and *Homo floresiensis*. Some researchers place the early species within the genus *Australopithecus*, and some refer to the later species as archaic *Homo* sapiens. This lab includes three exercises in which students examine and measure hominin cranial and postcranial fossil casts, as well as postcranial ape casts. It is assumed that students have a good working knowledge of anatomy from the textbook, lectures, and/or previous exercises.

Steps

- Before class, the instructor should organize fossil casts for students to analyze, either individually or in groups.
- For Exercise 1, students will need access to fossil crania casts of *Australopithecus africanus*, *Homo habilis*, *Homo erectus.*
- For Exercise 2, students will need access to fossil crania casts of *Homo erectus*, *H. heidelbergensis, H. neanderthalensis, and H. sapiens*.

- For Exercise 3, students will need access to pelvis and femur casts of an ape, *Au. afarensis*, *H. erectus*, *H. neanderthalensis*, and *H. sapiens*.
- Students will analyze casts, complete charts, and answer questions on the worksheet.

Review Questions

1. Identify the major species within the genus *Homo*.
2. Which features can we use to separate an australopithecine from a *Homo erectus* skull?
3. Specify major cranial differences between the *H. erectus*, *H. neanderthalensis*, and *H. sapiens*.
4. What are some broad trends that occurred over the course of *Homo* evolution? Discuss skull shape, facial morphology, and tooth or jaw proportions using specific examples from the different species, noting how they compare to each other.
5. *What changes have occurred to the breadth of the pelvic inlet over hominin evolution? What does this suggest about the social behavior and life history of the different hominin species?*

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Much of the data students will collect on the worksheets is descriptive or could be assessed without actually measuring. For online courses, using photographs and online 3D rotation images, students could compare the skulls and pelvic girdles of the species. Many resources are free to post in online course management systems. Additional options could be available with subscriptions or other licensing agreements.

See for example: https://africanfossils.org/, http://efossils.org/, https://sketchfab.com/, https://3d.si.edu/collections/hominin-fossils

References

Frank, Rebecca. 2019. “Activity 14: The Hominin Fossils: Australopithecines.” In *LAVC Anthro 111 Lab Manual*, 7th Edition, edited by Frank, Rebecca, Brian Pierson, and Philip Stein.

Paskey, Amanda and AnnMarie Beasley Cisneros. 2019. “Chapter 11: Archaic *Homo*.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Yoshida-Levine, Bonnie. 2019. “Chapter 10: Early Members of the Genus *Homo*.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Genus *Homo* Worksheet

Exercise 1: Genus *Homo*

We will begin our study of the genus *Homo* by comparing early species to *Au. africanus*. For this exercise, you will need skull casts of *Au. africanus*, *H. habilis*, and *H. erectus*. Measure and record the features in the chart, and then answer the questions below.

Feature	*Au. africanus*	*H. habilis*	*H. erectus*
Identify specimen you use			
Condylar Index = (Basion to Opisthocranion / Basion to Prosthion) x 100			
Location of maximum skull breadth as seen in the posterior view			
Relative degree of postorbital constriction as seen in the superior view			

Relative degree of prognathism as seen in the lateral view			
Facial Index = (Upper Facial Height / Cranial Height) x 100			
Relative size of supraorbital torus as seen in the anterior and lateral views			

Paleoanthropologists generally agree that *Homo erectus* belongs in our genus and represents a significant shift towards adaptations important to our own species. However, there is much variation among specimens that are grouped into *H. erectus*. Your instructor will let you know which of these fossil representatives to use for the exercise today.

Based on your measurements and comparisons in the table above, what are major differences among *Au. africanus*, *H. habilis*, and *H. erectus*? Do you think *H. habilis* is more like *Australopithecus* or *Homo*?

How do these three species reflect the major environmental pressures of the time periods in which they lived, respectively?

List three features that are changing in the genus *Homo* due to these selective pressures.

List three features found in *H. erectus* that are derived, compared to *Au. africanus*.

Exercise 2: Comparing Species of *Homo*

In this exercise, you will compare four species of *Homo*. You will again measure and calculate the Condylar Index and Facial Index and examine skeletal features of the face. Which features or indexes are getting larger? Which are getting smaller? What trends do you notice and what do these changes tell us about the selective pressures and adaptations observed in our genus? Measure and record the features in the chart and then answer the questions below.

Feature	*Homo erectus*	*Homo heidelbergensis*	*Homo neanderthalensis*	*Homo sapiens*
Identify specimen you use				
Condylar Index = (Ba to Op / Ba to Pr) x 100				
Location of maximum skull breadth posterior				
(Facial Height/ Cranial Height) x 100 = Facial Index				
Postorbital constriction superior view				
Degree of Prognathism, lateral view				
Relative size of incisors compared to molars				

Identify three major evolutionary trends that occurred in the genus *Homo* over the last two million years.

Discuss one of these trends and compare the *Homo* species using your measurements and observations to illustrate this trend. What are the likely reasons behind the changes that occurred in our genus?

Exercise 3: The Postcranial Skeleton

Hominins are defined largely on the basis of erect bipedalism so it is also important to examine the fossil evidence for locomotion. We will focus on the pelvis for this class, but adaptations of the femur and feet are also extremely important. Examine the pelves

from an ape, *Australopithecus afarensis*, *Homo erectus*, *Homo neandertalensis*, and *Homo sapiens.* Measure and record the features in the chart and then answer the questions.

Features	*Homo erectus*	*Homo neanderthalensis*	Modern Human
Identify specimen you use			
General shape of pelvis			
Position of iliac blade relative to spine			
Shape and direction of pelvic inlet			
Breadth / Height of pelvic inlet x 100 = Pelvic Inlet Index			
Size of anterior inferior iliac spine			
Ilium Breadth/ Ilium Height) x 100 = Ilium Index			

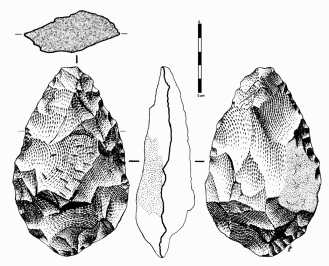
What differences do you see? Which species look most like modern humans? How have bodies and pelves changed over hominin evolutionary history?

Why is the breadth of the pelvic inlet important? What might it tell us about a species' social behavior or life history?

11.3: Brain, Language, Lithics

Brain, Language, Lithics

Format: In-person or online



Author: Perkl, Bradley

Time needed: 45 minutes

Learning Objectives

- Describe relationships between tool manufacture, increased brain size, and the development of language
- Differentiate between earliest and later stone tool technology.
- Understand changes in planning and teaching behaviors in early hominins

Supplies Needed

- Worksheet (provided)

Readings

- Wolcott Paskey, Amanda; Beasley Cisneros, AnnMarie. "Chapter 11: Archaic Homo". *Explorations*.

Chan, Keith. 2019. "Chapter 12: Modern Homo sapiens." *Explorations*.

Introduction

This lab explores how an aptitude for forethought allowed for the manufacturing of patterned, chipped stone tools. This is also associated with the ability to teach others to create stone tools. This process accompanied an increase in brain size and spurred the development of language in early hominins.

Steps

1. Students should be aware of increased brain size of hominins through time, of tool use, and how changing technology changed behaviors. If not, a brief tutorial at the beginning of class may help.
2. Provide examples of stone tools and lithic debitage for students to examine if available for in-person classes.
3. Students answer the questions in Exercise 1.
4. Students draw an example of an Oldowan and an Acheulean tool for Exercise 2.

Tips and Suggestions

1. Demonstrate making a chipped stone tool, or produce some flakes, if raw material and safety gear (safety glasses, gloves) are available. The instructor or a visiting expert can do this. Also consider having students create stone tools. Ensure that the lithic debris is properly disposed of in the trash (not thrown out-of-doors, which could confuse future archaeologists). Warning: chipped stone flakes and tools are sharp! Handle with caution.
2. Have students view some flintknapping videos (hundreds of these videos exist on Youtube) ahead of class or show a short video at the start of class. Note how the maker describes what they're doing: language in action.Teaching through language, gestures, etc. would also be observed/conducted in Tip 1 above).
3. Students can work in pairs or small groups as well. They will teach themselves.
4. Have fun.

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

Tips to adapt for an online learning activity: In place of using actual chipped stone tools, have students examine pictures (e.g., print, on-line, posters, etc.) of Oldowan and Acheulean artifacts for reference and make the drawings in Exercise 2 based on these images.

For Further Exploration

Everett, Daniel. 2017. *How Language Began: The Story of Humanity's Greatest Invention*. Liveright Publishing Corporation, New York.

Shea, John J. 2017. *Stone Tools in Human Evolution: Behavioral Differences Among Technological Primates*. Cambridge University Press, Cambridge.

Barnard, Allen. 2016. *Language in Prehistory*. Cambridge University Press, Cambridge.

Renfrew, Colin, Chris Firth, and Lambros Malafouris. 2009. *The Sapient Mind: Archaeology Meets Neuroscience*. Oxford University Press, Oxford.

References

Wolcott Paskey, Amanda; Beasley Cisneros, AnnMarie. 2019. Chapter 11: Archaic Homo in *Explorations: An Open Invitation to Biological Anthropology,* edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Dennell, Robin 2018. The Acheulean Assemblages of Asia: A Review. In R. Gallotti and M. Mussi (eds.), *The Emergence of the Acheulean in East Africa and Beyond: Contributions in Honor of Jean Chavaillon, Vertebrate Paleobiology and Paleoanthropology*, pp 198-214. https://doi.org/10.1007/978-3-319-75985-2_10

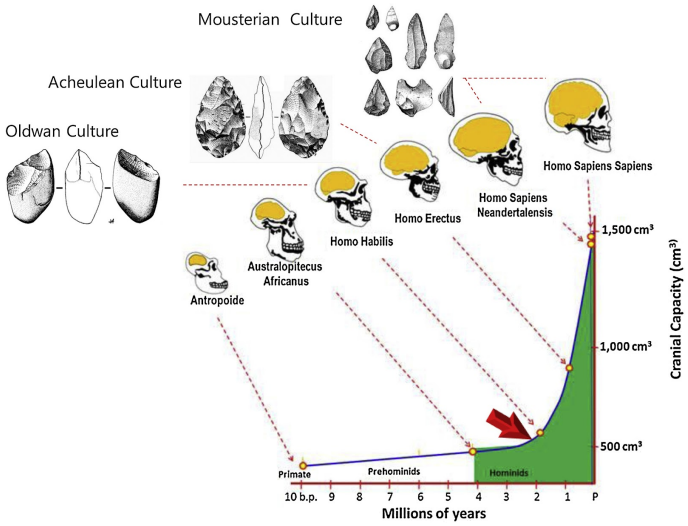
Capasso, Luigi, Elisabeth Michetti, and Ruggero D'Anastasio 2008. A *Homo Erectus* Hyoid Bone: Possible Implications for the Origin of the Human Capability for Speech. *Collegium Antropologicum* 32 (2008) 4: 1007-1011.

Image Attributions

Brain, Language, Lithics Worksheet

The manufacture of patterned, chipped stone tools by early hominins appears to have led to the co-evolution of manual praxis, language, and expansion of the brain. Between approximately 2.6 million years ago (mya) and 200,000 years before present (yrs

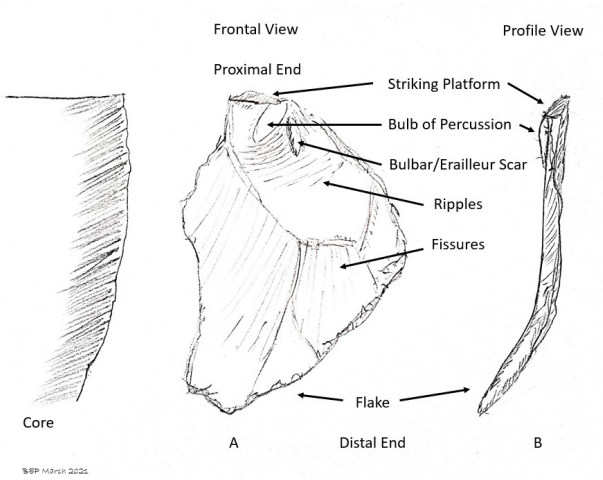
bp), the hominin brain nearly tripled in size, as indicated in the figure below.



Hominin Brain Size Through Time

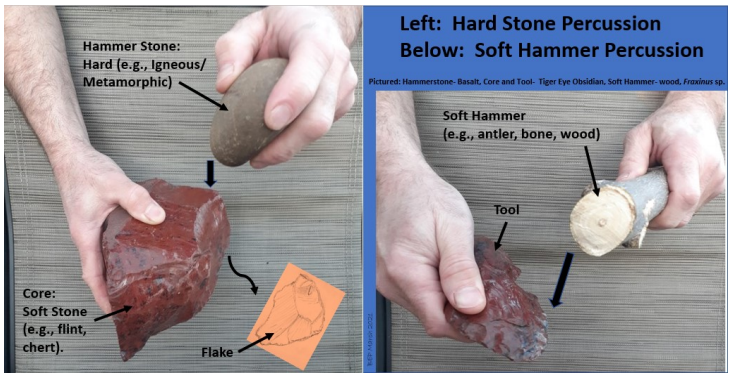
Some Points on Lithics

Stone (lithic) tool manufacture requires strong, fast, highly controlled (precise) manual praxis (finely attuned awareness and function of the hands). Manipulation of particular types of stone cores (e.g., silicate-based materials with predictable conchoidal fracture) will create a variety of flaked or chipped tools (e.g., chopper, hand axe, scraper, knife, projectile point). The cores, flakes, and tools made by early hominins and modern humans have specific characteristics that distinguish them from features caused by natural processes (e.g., heat, frost, a fall). These features include a striking platform, bulb of percussion, and ripples, as illustrated in the diagram below.



Features of a chipped stone flake. Two views (A: fontal; B: profile) of a flake struck from a core illustrate key characteristics of a purposely made flake.

Worked stone cores are percussed with (typically) harder materials (e.g., other rocks, bone, antler, wood) using a sharp, forceful blow to break off flakes in succession, removing pieces of the core to form the desired tool or finished product. Flakes may also be removed with hard (e.g., harder igneous or metamorphic based rocks) or soft (e.g., antler, bone, hard wood) hammers in carefully controlled strikes. The basic methods are illustrated in the diagram below.



Two basic percussion techniques

The complex motor tasks associated with stone tool production have a strong spatial-cognitive component that activates the neocortex (cerebrum) and cerebellum, which are the areas of greatest brain expansion in hominin evolution. The sometimes tedious and frustrating job of creating stone tools requires motivation, self-control, and future planning: the ability to visualize the final product and its use. Understanding the characteristics of the stone being worked, and the physics of lithic fracture, is necessary. Nuances to successfully create a tool include:, the angle on a lithic edge, the orientation of the percussive blow, and precise aim and timing. Many stone tools are discarded unfinished due to mistakes in knapping. Coincidently, these discarded waste flakes often signal an archaeological site. All of this knowledge is difficult to learn through self-teaching or imitation alone.

Debate continues as to who were the first toolmakers. There is some evidence from East Africa of stone tools associated with Australopithecines ca. 3.3 mya. However, by at least 2.6 mya the Oldowan industry appears in Africa. Oldowan tools may be associated with Australopithecines and/or *Homo habilis.* The Oldowan industry is composed predominantly of cores, which are lumps of stone that have been slightly modified by removing small pieces around the edges, hammerstones (identified from battering on their surfaces), and flakes struck from the cores offering sharp cutting edges. Flakes are very sharp and useful for butchering animal carcasses. Core choppers were also used to crack open bones to extract nutrient-rich marrow. These crude, simple choppers, and cutting tools are simplistic in design, yet they allowed early hominins to exploit a new niche: animal resources and meat eating. The following figures present some Oldowan tools.

Oldowan choppers from Melka Kunture, Ethiopia. Ca. 1.7 mya.

Drawing of an Oldowan chopper.

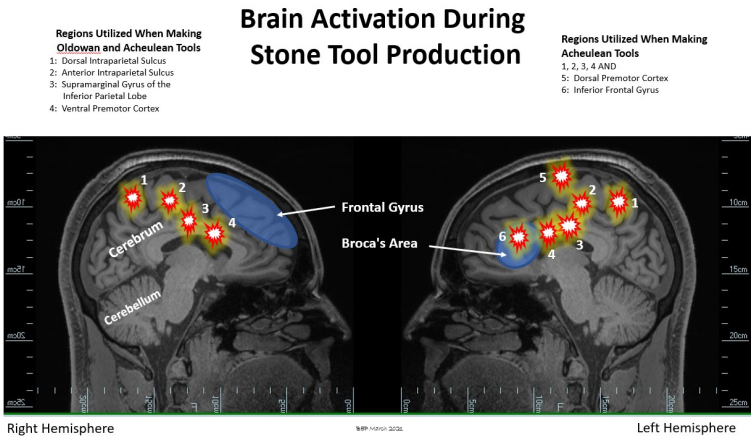
By 1.6 mya, bifacially worked cutting tools appear in the fossil record in Africa, known as the Acheulean Industry. The Acheulean toolkit is composed primarily of the hand axe, a teardrop-shaped tool. It also includes assorted cleavers which are characterized by large flakes that were shaped by striking smaller flakes from around two opposing sides-bifaces-to create sharp edges. The Acheulean stone tool industry that *Home erectus* used displays an advance over the earlier Oldowan tools. These tools are made with a mental template and a preconceived idea in mind; they are not simplistic like the Oldowan tools. The figures below depict Acheulean hand-axes.

Image on left: Handaxe from Isampur, India, about 1.1 million years old. © Copyright Smithsonian Institution.
Image on right: Handaxe from Meyral, France, about 250,000 years old. © Copyright Smithsonian Institution.

Acheulean Handaxe. Dordogne Region, France. Courtesy of the Science Museum of Minnesota.

Some Aspects of the Brain

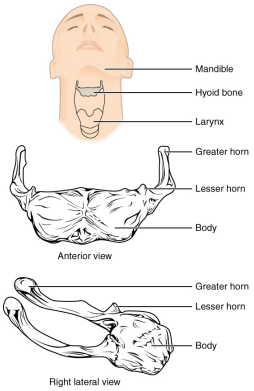
Stone tool production activates various areas of the brain, such as the cerebrum, cerebellum, and the frontal gyrus. One region in the frontal lobe, Broca's area, is associated with speech, language, music, math and complex manual actions (manual praxis). Scanning techniques (e.g., Magnetic Resonance Imaging, Positron Emission Tomography) of modern subjects creating stone tools reveal the different areas of the brain are activated when making relatively simple Oldowan tools and more complex Acheulean tools. The figure below reveals one indicator of expanded brain power with more sophisticated toolmaking. In the illustration, *numbers 1-4* denote regions active when making both Oldowan and Acheulean tools (i.e., dorsal intraparietal sulcus, anterior intraparietal sulcus, supramarginal gyrus of the inferior parietal lobe, ventral premotor complex). *Numbers 1-6* indicate regions utilized when making Acheulean tools (i.e., dorsal intraparietal sulcus, anterior intraparietal sulcus, supramarginal gyrus of the inferior parietal lobe, ventral premotor complex AND dorsal premotor cortex, inferior frontal gyrus).



Some Notes on Language

In the 19th century, Charles Darwin suggested a connection between the intellectual challenges associated with tool manufacture and language as seen in the extreme encephalization of modern humans. However, when toolmaking was observed in nonhuman species (e.g., Jane Goodall's report of chimpanzee tool use in the mid-20th century), toolmaking as a driver of evolution in humans fell out of favor. Recent research has brought new insights into how we have learned and taught each other to make tools - a process that may have enlarged our brains and spurred language. While imitation and practice are helpful, the nuances of strategy and tactics of stone tool manufacture are best learned from others, particularly via language. Increased manual praxis would allow for increased communication through gestures (associated with Broca's area), facial sensorimotor systems, and perhaps vocalizations.

It is not yet known what form of language early hominins/*Homo* had, which may have ranged from gestures, vocalization, and signs, to exosonatic (symbolic) and mimetic (imitative) forms. By approximately 500,000 years ago, the *Homo* brain had increased synaptic malleability and connectivity. In addition to a big brain, the capacity for spoken language includes morphological changes to the supralaryngeal airway (with a relatively enlarged oral cavity) and the hyoid bone. The hyoid bone is U-shaped and rests under the chin, supporting the tongue, and has a unique shape in the genus *Homo*. An approximately 400,000 year old *Homo erectus* hyoid bone from Italy is markedly different from chimpanzee and *Australopithecus afarensis* hyoid bones, suggesting that *Home erectus* had the capacity for speech. Genetic research has focused on the FOXP2 gene, the so-called 'gene for language'. A mutation in the gene occurring between 240,000-270,000 years ago in populations ancestral to living humans is implicated in motor control and cognition. This polymorphism allows for articulate language and enables the use of grammar. The figures below depict the position of the hyoid bone, its characteristics and a comparison with a chimpanzee hyoid bone.



Human hyoid bone

Human hyoid bone (left) and Chimpanzee hyoid bone (right)

The concurrent changes to the brain (increased connections and expansion) is a likely precursor to language (offering a significant learning advantage). Protolinguistic communication would be subject to selective pressure on the early hominin brain, producing adaptations that support language, along with physical adaptations to produce speech (i.e., the supralaryngeal airway, hyoid bone). Tools made by humans share a linguistic structure, as they are assembled in procedural ways (analogous to syntax) that have a nearly infinite capacity for variation (analogous to lexicon).

Exercise 1

Examine the examples of Oldowan and Acheulean stone tools in the figures above and then answer the following questions.

1. How do Oldowan tools build upon former tool technologies?
2. What behavior changes from australopithecines to early *Homo* may be occuring with the use of chipped stone tools?
3. What improvements in technology and style do you see in the Acheulean tools compared to Oldowan tools?

Exercise 2

In addition to physical changes to the vocal apparatus, genetic influence and other biological processes, different parts of the brain underlie language function and praxis.

Why would language be important in making stone tools?

Provide two examples of how language would benefit Homo.

CHAPTER OVERVIEW

12: Modern Homo sapiens

Learning Objectives

- Explore examples of modern human art
- Interpret the meanings of prehistoric and current art
- Construct hypotheses about the culture of the artists

12.1: Modern Human Art

Modern Human Art

Format: In-person or online

Rock art from 3000 years ago. What do you see?

Author: Dr. Keith Chan

Time needed: ~30 minutes

Supplies Needed

- Photographs (attached) or Internet connection
- Student worksheet (attached)

Readings

- Chan. 2019. Chapter 12: Modern *Homo sapiens*. *Explorations*.

Introduction

This activity will guide students through examples of modern human art with a focus on prehistoric art as well as one current piece of art. The goal is to explore the cultural side of human life over time by inferring meaning from their media. Students will use their interpretations of the details in the art to build scientific hypotheses that can be tested with other types of research, such as by examining skeletal remains found in the same region or the material culture of the artists.

Steps

1. Students could work individually or in teams.
2. Part 1: Students view art pieces, either as part of the additional documents or in color online. They will then learn a little about each one.
3. Part 2: Students will answer questions about each piece, leading to a guess about what it depicts and the purpose of its creation.
4. Part 3: In order to think scientifically about the study of art, students will conclude the lab by developing ways to test their interpretation with more data. For example, if the piece looks like a hunting scene, what type of archaeological evidence would align with that view?

Review Questions

The results of this lab are ideal discussion topics. Here are some examples :

1. For each piece: What does it show? How do you know?
2. Why do you think the artist created the piece?
3. How can researchers test hypotheses about the interpretation of each piece?

Adapting for Online Learning

Rank how adaptable to online learning this lab is:

Tips and Suggestions

Another way to do this lab in a face-to-face class would be to project the art from the web links and have the class work in tandem to complete the worksheets. Another option would be to use art of your choice or have students find the art.

References

Chan, Keith. 2019. “Chapter 12: Modern *Homo sapiens*.” *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Banksy. (2008). Cave Painting Removal [Graffiti]. Leake Street Tunnel, London, UK. Photograph by Beckett, Chris. (2008). Banksy, Council worker cleaning up the cave paintings - The Cans Festival, Waterloo, London. CC BY-NC-ND 2.0. https://flic.kr/p/4KQfgT.

Catron, Scott. (2006). HuntSceneNMC [Photograph of rock art]. https://commons.wikimedia.org/wiki/File:HuntSceneNMC.JPG. CC BY-SA 3.0.

The Met. (n.d.). Plaque: Equestrian Oba and Attendants [Photograph of metal sculpture]. https://www.metmuseum.org/art/collection/search/310752. Public Domain.

Pouliquin, Pierre. (2004). Untitled [Photograph of rock art]. https://flic.kr/p/ffNH2. CC BY-NC 2.0. The color has been adjusted.

Retlaw Snellac Photography. (2008). Azerbaijan [Photograph of rock art]. https://flic.kr/p/5FpN2s. CC BY 2.0.

Modern Human Art Worksheet

Part 1. Examples of Human Art

View five pieces of art, either with the attached materials or online. Some context is provided for each piece.

Part 2. Art Interpretation

For each art piece, answer the following questions on a separate document:

1. What objects, actions, or things appear in the artwork? What do you think is happening in the artwork? Specifically try to identify what is being depicted and describe the overall scene.

2. Why do you think the artist made this piece?

Part 3. Scientific Hypotheses

3. Make hypotheses to test your answers from Part Two. What kinds of evidence from subdisciplines of anthropology (i.e. cultural anthropology, archaeology, linguistic anthropology, and/or biological anthropology) could support your interpretation? For example, if you think the piece depicts warfare, archaeology could be used to look for artifacts matching the weapons that the artist drew or one might want to examine skeletons from that culture for injuries from these types of weapons. If the piece depicts an animal, what kind of evidence would show that it was based on a real organism? Get creative and think widely of where the evidence could come from. Look in the textbook for ways that researchers have studied culture and cultural remains.

Additional Images: Art Pieces

1. Petroglyph (rock art) found in the Nine-Mile Canyon, Utah (Catron, 2006). The piece is approximately the size of a couch.

2. Plaque cast in bronze from the Edo people of Nigeria. The date is from 1550 to 1680 (The Met, n.d.). It is just under 20 inches tall and would have been mounted on the wall of a building.

3. Rock art in Carnarvon National Park, Australia, attributed to aboriginal peoples (Pouliquin, 2004). Be sure to consider the grid to the right and the three-pronged shapes to the left in your interpretation. The hands are life size.

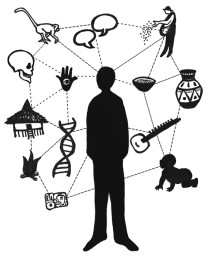
4. Petroglyph from Qobustan, Azerbaijan dating to between 1300 to 900 BC. The piece is around three feet high.

5. Graffiti by the mysterious contemporary artist Banksy. It was made in 2008 in a London tunnel where graffiti was allowed (Banksy, 2008). The figure is life size. Imagine viewing this piece without knowledge of the figure's culture.

12.2: What Does it Mean to be Human?

What Does it Mean to be Human?

Format: In-person or online



Author: Anne E. Pfister

Time needed: 30-40 minutes

Learning Objectives

- Analyze the traditional categories for human ancestors.
- Evaluate the human traits that are most essential to modern humans.

Supplies Needed

- Yellow sticky notes (if in-person)
- Handout (provided, if in-person)
- Discussion board (if online)

Readings

- Chan, Keith. 2019. Chapter 12: Modern Homo sapiens. *Explorations*.

Introduction

This activity helps students understand that there is no one defining moment in human evolutionary history when we "become human." This is a great culminating activity after a unit of study on human ancestors, when students often have more questions about our evolutionary history than firm answers.

Steps

1. Distribute the worksheet (attached).
2. In the worksheet, ask students to generate the characteristics of modern humans. After giving them time to think about the list, ask them to prioritize the characteristics and choose one or two of the most important to write on a sticky note.
3. Distribute sticky notes to students (1-2 per student, depending on instructor preference and class size).
4. *Ask students to write on a sticky note 1-2 defining characteristics of humans. In other words: what makes humans different from any other living species today? Remind students that there are no right or wrong answers, but to choose the characteristic(s) they find most specific to our species. I don't typically give them examples, but examples include: a clear sense of self; language; religion; belief in an afterworld; forethought/planning; compassion; etc. The sticky notes can be anonymous as their purpose is to generate discussion.*
5. *Instruct students to quietly put their sticky note on a whiteboard or a similar common area where the instructor can read the comments after everyone has contributed.*
6. *Once all students have pasted their sticky notes, the instructor reads what is inevitably a diverse list of characteristics.*
7. *Discuss students' impressions of the list, pointing out again that all the traits (and more) are indeed characteristics of humans and that through the slow and cumulative processes of evolution, the characteristics have been refined. The discussion could also summarize how some characteristics can be traced to other "species" that came before modern humans.*
8. *Wrap up the discussion by acknowledging the persistent misunderstandings that many people have about human evolution: that it was a stepwise process, or that there were drastic changes, or that pre-humans are often thought of as drastically different than us (even though many shared some of the characteristics that students identified as uniquely human).*
9. *Ask students to write their impressions of the discussion or take-away points as well as any questions they still have and collect their responses (if grading this activity/discussion).*

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

One could adapt this activity by using the discussion board of an online learning management system. Students could post a first response that includes the traits they identify as uniquely human and then they could respond to their classmates.

For Further Exploration

-
- What does it mean to be human website: https://humanorigins.si.edu/human-characteristics

References

Image Attributions

Holism original to Explorations: An Open Invitation to Biological Anthropology by Mary Nelson is under a CC BY-NC 4.0 License.

What Does it Mean to be Human? Worksheet

Answer each question in the space provided below.

BRAINSTORM *What are the fundamental characteristics of being human?*	ASK *What questions do you have?*

TAKE-AWAY IDEAS *Write a summary of the discussion or take-away ideas, as well as any questions you still have.*

CHAPTER OVERVIEW

13: Race and Human Variation

Learning Objectives

- Identify that human biological traits are distributed in non-concordant patterns
- Recognize that patterns of human variation do not fit discrete racial groups
- Use biological anthropological terms to describe patterns of human variation

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13.1: Patterns of Human Variation - online

Patterns of Human Variation: Online

Format: Online

Human diversity

Author: Beth Shook

Time needed: 20-30 minutes

Supplies Needed

- Google Slides Patterns of Human Variation presentation (template provided here)

Readings

-

Introduction

This activity is intended to be completed synchronously using an online communication platform, such as Zoom. A group of 10 to 16 students works best. If the class is larger, students could be placed into breakout groups after the instructions are presented.

The activity utilizes Google Slides to depict a small population, with traits typical of some American classrooms, as silhouettes on a slide. Each student selects a silhouette to role play. Each of these silhouettes have assigned characteristics (such as height and blood type). Students will synchronously move and organize their silhouettes by the trait named on the slide. Some of these traits are organized in discrete groups, while others are continuous. Students will represent the same silhouette for the entire activity.

Steps

- Students should be introduced to patterns of human variation ahead of time, either in class and/or through reading (e.g. *Explorations* Chapter 13). Terms and concepts that are important to define include: polymorphism, continuous variation, cline (or clinal distribution), and non-concordance.
- Instructors can make a copy of the Google Slides provided. Instructors can then share with students a link to the copy of the Google sides. Instructors should change the “Share” settings to provide their students with “editor” access.
- Each student selects a silhouette on the “height” slide (the first silhouette slide). Any silhouettes not selected can be deleted from the height slide and all following slides, or can be selected and moved around by the instructor.
- For the “height” slide (the first silhouette slide), students should be instructed to move their silhouettes around to organize them from shortest (left) to tallest (right), based on the height written on the silhouette. Students can click and drag, or use arrows, to move their silhouettes.
- Once students have arranged their silhouettes, they should be advised to look at which silhouettes they are next to, and watch future slides to see if their silhouette regularly ends up next to the same members of the population, or different ones.
- The class should then proceed to the next trait. For discrete traits like blood types, silhouettes are to be sorted into the provided boxes that correspond with the silhouette’s phenotype (e.g. blood type A, B, AB, or O).
- Work through all the trait slides, encouraging students to think about which silhouettes they are grouped near each time and noting if they are always with the same individuals or different ones.

Conclusion

Ask students if they found that they were regularly next to the same individuals (silhouettes) or if they were often grouped with different individuals. Most students should find that they are grouped with different people each time, although it is possible that this varies (especially if they exhibited common traits, like O blood type). The frequencies of these traits are similar to American college students in general. When many traits are examined, students should see that humans do not fall into discrete groups or "races."

Ask students to explain or provide an example of the following terms/concepts based on the traits that were examined:

- Polymorphism,
- Continuous variation,
- Clinal distribution,
- Non-concordance of traits, and
- Genetic diversity Is greater within-group than between-groups.

For example, students may say "height is a continuous variable" or "the pattern for lactose tolerance is very different from that of skin color, demonstrating non-concordance".

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This lab is an online adaptation of a classic lab activity where students sort themselves in the classroom by the traits they exhibit. For example, the instructor may have them line up by height across the center of a classroom, or have students who can roll their tongue go to one wall and those who cannot go to the opposite wall. This version is intended to be done in a synchronous online (e.g. Zoom) classroom.

For Further Exploration

The Race Project. Are We So Different? American Anthropological Association.

https://understandingrace.org

References

Rivera, Michael. 2019. "Chapter 13: Race and Human Variation." In *Explorations: An Open Invitation to Biological Anthropology,* edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Diversity, Differences, Qualities, Uniqueness by johnhain is used under a pixabay license.

13.2: Patterns of Human Variation - in person

Patterns of Human Variation

Format: In Person

Human diversity

Inspired by a classic class activity used in classrooms across the nation (origin unknown) and by The Human Spectrum activity from The Race Project. Are We So Different? American Anthropological Association.

Time needed: 20-30 minutes

Learning Objectives

- Identify that human biological traits are distributed in non-concordant patterns
- Recognize that patterns of human variation do not fit discrete racial groups
- Use biological anthropological terms to describe patterns of human variation

Supplies Needed

- Instructions

Readings

-

Introduction

This short activity explores the biological variation among students in a class. Students stand and move around the classroom organizing themselves based on the characteristics that they exhibit. Students will then look for patterns in the variation exhibited in the classroom and should recognize, by the end, that patterns of human variation do not fit discrete racial groups.

Steps

- Students should be introduced to patterns of human variation ahead of time, either in class and/or through reading (e.g. *Explorations* Chapter 13). Terms and concepts that are important to define include: polymorphism, continuous variation, cline (or clinal distribution), and non-concordance.
- Students should be instructed that they will be organizing themselves into groups or in a long line based on their individual expression of a trait that the instructor names. As students move into a new place, they will need to note who they are grouped with. They should observe whether they are always with the same individuals, or if they cluster with different students for most of the traits
- The instructor should proceed through the traits listed below, directing students to the location they should stand in the room based on their traits. For example, “Please organize yourselves by height. Form a line against the back wall with the tallest students by the door and the shortest students by the window.” Some traits are discrete and may require additional directions. For example, “If you know your ABO blood type, please move to the wall that corresponds with your blood type. The north wall is A, west is B, south is AB, and east is O. If you do not know your blood type you can stand in the middle of the classroom.”
    - Hair color
    - Blood types (A, B, O, A/B)
    - Whether or not your tongue curls

- Lactose tolerance or intolerance (ability to digest milk products)
- Left-handedness or right-handedness
- Fingerprint types (loop, whorl, arch or tented arch)
- Straight vs curly hair and in between
- Presence of freckles
- Height
- Skin color (compare the inside of your arm)

Conclusion

Ask students if they found that they were regularly next to the same individuals or if they were often grouped with different individuals. Most students should find that they are grouped with different people each time, although it is possible they may share a number of traits with any one person (especially if they exhibit common traits, like O blood type). When many traits are examined, students should see that humans do not fall into discrete groups or "races."

Ask students to explain or provide an example of the following terms/concepts based on the traits that were examined:

- Polymorphism,
- Continuous variation,
- Clinal distribution,
- Non-concordance of traits, and
- Genetic diversity is greater within-group than between-groups.

For example, students may say "height is a continuous variable" or "the pattern for lactose tolerance is very different from that of skin color, demonstrating non-concordance".

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

This activity has been adapted for a synchronous online (e.g. Zoom) class and instructions are posted with other Chapter 13 Explorations Lab and Activities under the title Patterns of Human Variation: Online.

For Further Exploration

The Race Project. Are We So Different? American Anthropological Association.

https://understandingrace.org

References

Rivera, Michael. 2019. "Chapter 13: Race and Human Variation." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

Diversity, Differences, Qualities, Uniqueness by johnhain is used under a pixabay license.

CHAPTER OVERVIEW

14: Human Adaptive Significance Approach

Learning Objectives

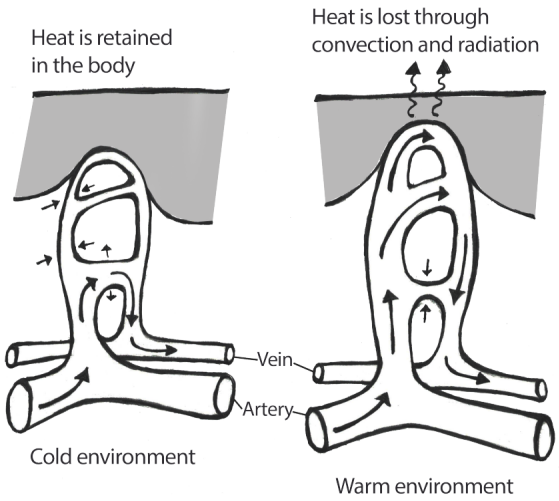
- Observe how the body regulates temperature
- Apply both a qualitative and a quantitative test
- Evaluate the difference between “adjustments” and “adaptations”
- Document and compare the body’s physical reaction to different stressors

Thumbnail: This depicts the vasoconstriction process that occurs when an individual is exposed to cold temperatures and the vasodilation that occurs in warm temperatures.

14.1: Thermal Stressors

Thermal Stressors

Format: In-person or online



This depicts the vasoconstriction process that occurs when an individual is exposed to cold temperatures and the vasodilation that occurs in warm temperatures.

Authors: Sydney Quinn Chizmeshya and Katherine E. Brent

Sources: Adapted from Doris Hexsel et al. 2010. Recommendations for Performing and Evaluating the Results of the Minor Test According to a Sweating Intensity Visual Scale. *Dermatologic Surgery.*

Adapted from Sigfrid A. Muller and Robert R. Kierland. 1959. The Use of a Modified Starch-Iodine Test for Investigating Local Sweating Responses to Intradermal Injection of Methacholine. *Journal of Investigative Dermatology.*

Time needed: 30 - 40 minutes

Supplies Needed

- Timer
- Cold source (e.g. ice cubes, cold pack)
- Heat source (e.g. hair dryer, hand warmers)
- Blank paper cut into small squares of 3x3 cm (4 per group)
- Cotton balls (24 per group)
- Rubbing alcohol
- Iodine
- Cornstarch
- Student worksheet (attached)

Readings

-

Introduction

This lab allows students to experience thermal stressors on a small scale so as to observe the benefits of and physical reactions associated with thermoregulation and homeostasis. Furthermore, this activity will allow the students to explore the nuances of “adjustments” and “adaptations,” as defined in Chapter 14 of *Explorations*. The lab includes two scientific procedures: the Minor Test (which is qualitative), and Randall’s Modification to the Minor Test (which is quantitative).

Steps

- Organize the class into small groups (consisting of 4 or 5 students). Each group should have the following materials:
  - Timer
  - Cold source (e.g. ice cubes, cold pack)
  - Heat source (e.g. hair dryer, hand warmers)
  - Blank paper cut into small squares of 3x3cm (4 per group)
  - Cotton balls (24 per group)
  - Rubbing alcohol
  - Iodine
  - Cornstarch
  - Student worksheet(s) (attached)
- Students will follow the directions on their worksheet to complete the activity. This laboratory exercise consists of four experiments, and each experiment should be undertaken by a different individual in the group, and then discussed among group members.
  - 1. Heat stress exposure
  - 2. Cold stress exposure
  - 3. Exercise/heart rate increase exposure
  - 4. A control exercise with no stressor.
- When the activity has been completed, reunite the class for a discussion based on the review questions below.

Review Questions

1. What do the dots on the paper pressed to the left palm represent? (*Answer*: the dots quantify the activation of sweat glands.)
2. What does a color change on the right palm represent? (*Answer*: the color change is a qualitative measure of the activation of sweat glands.)
3. What does sweating accomplish for the body? (*Answer*: Sweating is the body's attempt to lower overall body temperature and maintain homeostasis.)
4. What does shivering accomplish for the body? (*Answer*: Shivering is the body's attempt to raise overall body temperature through heat generation to maintain homeostasis.)
5. How is body temperature regulated in humans? (*Answer*: The hypothalamus, a small part of the brain, regulates body temperature.)
6. What are the differences between "adjustments" and "adaptations" in relation to human evolution? (*Answer*: Adjustments can be behavioral, acclimatory, or developmental, and occur exclusively at the individual level. Adjustments are non-genetic coping mechanisms used to face environmental stressors. They are temporary in nature. On the other hand, adaptations are genetic and micro-evolutionary, permanent in nature, and occur at the population level.)
7. Why do we turn paler in response to cold, and redder in response to heat? Is this an example of an adaptation or an adjustment? (*Answer*: Paleness is a result of vasoconstriction and redness is a result of vasodilation. These are examples of adjustments.)

Adapting for Online Learning

1 Not adaptable **2 Possible to adapt** 3 Easy to adapt

With clear directions students could complete the experiment in their home, though they may need to purchase some supplies. Additionally, using heat and cold sources irresponsibly could be dangerous, so instructors should provide cautions. Instructors could alternatively record a short video showing the experiment for students to watch and reflect on at home.

For Further Exploration

Cognito. GCSE Biology - How We Control Our Body Temperature #73. https://www.youtube.com/watch?v=IGsQi0JZUTw

FuseSchool - Global Education. Temperature Regulation of the Human Body - Physiology - Biology. https://www.youtube.com/watch?v=vJhsyS4lTW0

John Murnan. TED-Ed Lesson: Why do we sweat? https://ed.ted.com/lessons/why-do-we-sweat-john-murnan

References

Fitzpatrick, Leslie. 2019. “Chapter 14: Human Variation: An Adaptive Significance Approach.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Hexsel, Doris, Ticiana C. Rodrigues, Mariana Soirefmann, and Debora P. Zechmeister-Prado. 2010. “Recommendations for Performing and Evaluating the Results of the Minor Test According to a Sweating Intensity Visual Scale.” *Dermatologic Surgery, 36*(1): 120-122.

Muller, Sigfrid A., and Robert R. Kierland. 1959. “The Use of a Modified Starch-Iodine Test for Investigating Local Sweating Responses to Intradermal Injection of Methacholine.” *Journal of Investigative Dermatology 32*(2): 126-128.

Image Attributions

Vasoconstriction and vasodilation (Figure 14.4) from *Explorations: An Open Invitation to Biological Anthropology* by Mary Nelson is under a CC BY-NC 4.0 License.

Thermal Stressors & Homeostasis: Investigating Adjustments Worksheet

Background

In the following laboratory activity, you will explore your body’s physical reaction to small-scale thermal stressors using two scientific procedures: the Minor Test, and Randall’s Modification to the Minor Test. Both tests explore sweat gland responses, but while the Minor Test is qualitative, Randall’s Modification is quantitative.

Upon completion of this activity, you will have:

- Explored the body’s ways of regulating temperature,
- Critically evaluated the difference between “adjustments” and “adaptations”
- Experienced and documented the body’s physical reaction to stressors.

Lab Kit Materials

- Timer
- Cold source (e.g. ice cubes, cold pack)
- Heat source (e.g. hair dryer, hand warmers)
- Blank paper cut into small squares of 3x3cm (4 per group)
- Cotton balls (24 per group)
- Rubbing alcohol
- Iodine
- Cornstarch

Instructions

This laboratory exercise consists of four experiments: (1) heat stress exposure, (2) cold stress exposure, (3) exercise/heart rate increase exposure, and (4) a control exercise with no stressor.

Each experiment should be undertaken by a different individual and assisted by their group members. Decide ahead of time which experiment (heat, cold, exercise, control) will be done by which group member. If there is a fifth group member, that individual should be the group’s recorder.

Additionally, ensure that you use a fresh cotton ball for each swab application to ensure no cross-contamination.

Part 1: Heat Stress - For Group Member #1

1. Using rubbing alcohol on a cotton ball, swab the left palm. Let it dry completely. Once the alcohol has dried, swab the same palm with iodine. Let the iodine dry completely.
2. Apply iodine to a fresh cotton ball and swab the right palm directly. Let it dry completely. Once the iodine has dried, apply cornstarch to the right palm using a fresh cotton ball.
3. Apply the heat source to both palms for 5 minutes. During this time, pay attention to any visual changes that occur on the right palm.
4. Once five minutes have elapsed, press a square of blank paper firmly into the left palm for approximately 30 seconds.

5. Record the number of dots you see on the paper pressed into the left palm in the respective box in the activity chart.
6. Record physical observations you see on the right palm in the respective box in the activity chart.
7. Record physical sensations or visual observations you made about your body during the experiment in the respective box in the activity chart.

Part 2: Cold Stress - For Group Member #2

1. Using rubbing alcohol on a cotton ball, swab the left palm, Let it dry completely. Once the alcohol has dried, swab the same palm with iodine. Let the iodine dry completely.
2. Apply iodine to a fresh cotton ball and swab the right palm directly. Let it dry completely. Once the iodine has dried, apply cornstarch to the right palm using a fresh cotton ball.
3. Apply the cold source to both palms for 5 minutes. During this time, pay attention to any visual changes that occur on the right palm.
4. Once five minutes have elapsed, press a square of blank paper firmly into the left palm for approximately 30 seconds.
5. Record the number of dots you see on the paper pressed into the left palm in the respective box in the activity chart.
6. Record physical observations you see on the right palm in the respective box in the activity chart.
7. Record physical sensations or visual observations you made about your body during the experiment in the respective box in the activity chart.

Part 3: Exercise Stress - For Group Member #3

1. Using rubbing alcohol on a cotton ball, swab the left palm, Let it dry completely. Once the alcohol has dried, swab the same palm with iodine. Let the iodine dry completely.
2. Apply iodine to a fresh cotton ball and swab the right palm directly. Let it dry completely. Once the iodine has dried, apply cornstarch to the right palm using a fresh cotton ball.
3. Perform jumping jacks for 5 minutes. During this time, pay attention to any visual changes that occur on the right palm.
4. Once five minutes have elapsed, press a square of blank paper firmly into the left palm for approximately 30 seconds.
5. Record the number of dots you see on the paper pressed into the left palm in the respective box in the activity chart.
6. Record physical observations you see on the right palm in the respective box in the activity chart.
7. Clean both palms with a cotton ball and rubbing alcohol.
8. Record physical sensations or visual observations you made about your body during the experiment in the respective box in the activity chart.

Part 4: Control With No Stress - For Group Member #4

1. Using rubbing alcohol on a cotton ball, swab the left palm, Let it dry completely. Once the alcohol has dried, swab the same palm with iodine. Let the iodine dry completely.
2. Apply iodine to a fresh cotton ball and swab the right palm directly. Let it dry completely. Once the iodine has dried, apply cornstarch to the right palm using a fresh cotton ball.
3. Rest for 5 minutes. During this time, pay attention to any visual changes that occur on the right palm.
4. Once five minutes have elapsed, press a square of blank paper firmly into the left palm for approximately 30 seconds.
5. Record the number of dots you see on the paper pressed into the left palm in the respective box in the activity chart.
6. Record physical observations you see on the right palm in the respective box in the activity chart.
7. Record physical sensations or visual observations you made about your body during the experiment in the respective box in the activity chart.

Observations

	Randall Modification: Number of Dots (Left palm)	**Minor Test:** Physical Observations (Right palm)	**Physical Feelings, Sensations, and Observations**
HEAT Exposure (5 minutes)			
(5 minutes)			
EXERCISE (5 minutes of jumping jacks)			

CONTROL (5 minutes rest)			

Reflection

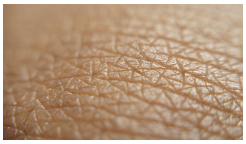
After you have recorded your observations in the table above, discuss the following questions with your group:

1. What do the dots on the paper pressed to the left palm represent?
2. What does a color change on the right palm represent?
3. What does sweating accomplish for the body?
4. What does shivering accomplish for the body?
5. How is body temperature regulated in humans?
6. What are the differences between “adjustments” and “adaptations”? How are they relevant to understanding human evolution?
7. Why do we turn paler in response to cold, and redder in response to heat?

14.2: Human Skin Color Variation - Part I

Human Skin Color Variation - Part 1

Format: In-person or online



A close-up photograph of human skin

Author: Nelson, Katie

Time needed: 60 minutes

Learning Objectives

- Describe and illustrate the cellular process that produces skin color.

Supplies Needed

- Internet access
- Worksheet (provided)

Readings

-
-

Introduction

The purpose of this activity is for students to understand the cellular process that produces skin color and the evolution of skin color variation. By doing so, students will be able to question ideas about the alleged biological basis of race. This is part one of a two part learning activity. In this part, students watch a short video produced by Howard Hughes Medical Institute (HHMI) Biointeractive to learn about the biology of human skin color. Students summarize the content in the video and illustrate the cellular process that produces skin color. This part lays the foundation for the explorations of the evolution of skin color variation in part two.

Steps

1. In step one, students watch the video How We Get Our Skin Color produced by HHMI BioInteractive. This video describes how skin pigment is generated by skin cells as protection against ultraviolet (UV) radiation.
2. Students answer a series of questions designed to help them understand the process.
3. Finally, students demonstrate what they have learned by drawing a diagram that summarizes the cellular process that produces skin color.

Tips and Suggestions

At the end of the second part of this activity, students explore the concept of non-concordance and skin color and some of the evidence of the biological fallacy of race. To support this, I recommend emphasizing that the cellular process of skin color production is the same for every human and that one's baseline skin color is inherited independently of other genetically controlled genes.

If desired (to shorten the time required), instructors may reduce the number of questions on the worksheets.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

- American Anthropological Association. Understanding Race Project.
- Jablonski, Nina G. 2012. *Living Color: The Biological and Social Meaning of Skin Color*. Berkeley, CA: University of California Press.
- Jablonski, Nina G. 2004. "The Evolution of Human Skin and Skin Color." *Annual Review of Anthropology* 33 (2004): 585–623.

References

Fitzpatrick, Leslie E. 2019. Chapter 14: Human Variation: An Adaptive Significance Approach. In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Rivera, Michael B.C. 2019."Chapter 13: Race and Human Variation" In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

HHMI Biointeractive. The Biology of Skin Color. Narrated by Nina Joblanski. Chevy Chase, MD, HHMI Biointeractive, 2020. Video, 18:58.

HHMI Biointeractive. How we Get our Skin Color. Narrated by Nina Joblanski. Chevy Chase, MD, HHMI Biointeractive, 2015. Video, 3:32.

Image Attributions

Human skin close-up by Montavius Howard (TongCreator), from Pixabay is in the public domain.

Human Skin Color Variation Part 1 Worksheet

Step One: Exploring the Biology of Skin Color

Watch the video How We Get Our Skin Color produced by HHMI BioInteractive. This video describes how skin color is generated by skin cells as protection against ultraviolet (UV) radiation. Then answer the following questions. You may wish to watch the video several times or pause the video as you complete your answers.

1. List the three layers of skin and indicate which layer of skin gives humans their skin color.
2. Briefly describe the functions of keratinoctyes and melanocytes.
3. Describe the cellular process that produces skin color. Be sure to include the following terms: malanosome, melanin, tyrosine, keratinocytes

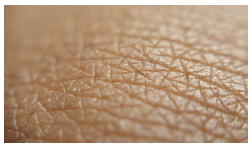
4. How does melanin protect the cells from UV radiation? What are the risks of UV radiation?
5. Briefly state what determines an individual's baseline skin color and how much it can tan.
6. Draw a simple diagram that illustrates this entire process of skin pigment production, as described in the video. Your diagram must include the following terms: malanosomes, melanin, tyrosine, keratinocytes, melanocytes, epidermis, dermis, hypodermis. Your diagram does not necessarily need to be artistically beautiful, but should demonstrate your understanding of this process. Be sure to label each part and process. You are welcome to write descriptions of processes in the margins of the diagram.

Diagram: skin pigment production

14.3: Human Skin Color Variation - Part II

Human Skin Color Variation - Part 2

Format: In-person or online



A close-up photograph of human skin

Author: Nelson, Katie

Time needed: 60 minutes

Learning Objectives

- Evaluate the hypothesis that human skin color tones differ in relation to levels of ultraviolet radiation exposure.
- Summarize the positive and negative selective factors that account for differences in human skin colors.

Supplies Needed

- Internet access
- Worksheet (provided)

Readings

-
-

Introduction

In part one of this activity, students learned about the cellular process that produces skin color. In this part, students explore the evolution of skin color variation. By doing so, students will be able to question ideas about the alleged biological basis of race. In this part, students watch another video produced by Howard Hughes Medical Institute (HHMI) Biointeractive and evaluate the hypothesis that different tones of skin color in humans arose as adaptations to intensity of ultraviolet radiation in different parts of the world. They then summarize and illustrate the positive and negative selective factors that account for the differences in skin colors among human populations. Finally, students consider that most human traits, including skin color are non-concordant and inherited independently of other genetically controlled traits. They then consider this as a piece of evidence of the biological fallacy of race and articulate what they learned using terminology accessible to a wide audience.

Steps

1. Students watch the film The Biology of Skin Color produced by HHMI BioInteractive. This film explores the hypothesis that different tones of skin color in humans arose as adaptations to the intensity of ultraviolet radiation in different parts of the world.
2. Similar to step one, students answer a series of questions and then draw a diagram that illustrates the positive and negative selective factors that account for the differences in skin colors among human populations.
3. Finally, students write one or two paragraphs, summarizing what they have learned in this activity. Writing as if they were talking to a friend who knows little about this subject, they explain how skin pigment is produced and why it varies among people throughout the world

Tips and Suggestions

At the end of this activity, students explore the concept of non-concordance and skin color and some of the evidence of the biological fallacy of race. Be sure to emphasize that while race is not a biological reality, race and racism are social realities that can affect our biology. That is, many believe that race is a real and legitimate way to categorize people and that phenotypical differences such as skin color are related to something deeper in one's biology. People also use racial categories in self (and other) identification. Racism significantly impacts peoples lives and health, privileging some and disadvantaging others. I recommend closing with a discussion of the danger of being "color blind". We must acknowledge how, in the U.S., the social construction of race has disproportionately disadvantaged people with darker skin tones and provided unearned advantages for those with light skin tones.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

- American Anthropological Association. Understanding Race Project.
- Jablonski, Nina G. 2012. *Living Color: The Biological and Social Meaning of Skin Color*. Berkeley, CA: University of California Press.
- Jablonski, Nina G. 2004. "The Evolution of Human Skin and Skin Color." *Annual Review of Anthropology* 33 (2004): 585–623.

References

Fitzpatrick, Leslie E. 2019. Chapter 14: Human Variation: An Adaptive Significance Approach. In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Rivera, Michael B.C. 2019."Chapter 13: Race and Human Variation" In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

HHMI Biointeractive. The Biology of Skin Color. Narrated by Nina Joblanski. Chevy Chase, MD, HHMI Biointeractive, 2020. Video, 18:58.

HHMI Biointeractive. How we Get our Skin Color. Narrated by Nina Joblanski. Chevy Chase, MD, HHMI Biointeractive, 2015. Video, 3:32.

Image Attributions

Human skin close-up by Montavius Howard (TongCreator), from Pixabay is in the public domain.

Human Skin Color Variation Part 2 Worksheet

Step Two: Understanding the Evolutionary Pressures of Skin Color

Begin this step after completing step one in part one of this activity. Now, watch the film The Biology of Skin Color produced by HHMI BioInteractive. This film explores the hypothesis that different tones of skin color in humans arose as adaptations to the intensity of ultraviolet radiation in different parts of the world. Then, answer the following questions.

1. What color skin do chimpanzees have under their fur?
2. What type of melanin do lightly pigmented people have?
3. What type of melanin do more darkly pigmented people have?
4. What other body parts does melanin color? What does melanin do for other species?
5. What kind of raw data helped Dr. Nina Jablonski find the answer to her questions about the relationship between UV radiation and human skin pigmentation?
6. In general terms, how is UV radiation intensity distributed throughout the world?
7. How do scientists measure skin color?
8. Why are folate and vitamin D important nutrients?
9. Describe the selective pressures for the production of darkly pigmented skin in areas with high UV radiation intensity.
10. Describe the selective pressures for the production of lightly pigmented skin in areas with low UV radiation intensity.
11. Describe the evolutionary interplay between folate and vitamin D.
12. What do scientists infer from the lack of variation in the MC1R gene among African populations?
13. Why are light skinned people at greater risk for skin cancer than dark skinned people?
14. Why might dark skinned people living in high latitude environments need to take a vitamin D supplement? (Note: please always consult your doctor before starting any supplement regimen).
15. Now design a diagram that illustrates the positive and negative selective factors that account for the differences in skin colors among human populations.

Diagram: selective factors for skin color variation

Step Three: Bringing it all Together

As Michael Rivera discusses in chapter 13, most human traits, including skin color, are non-concordant. That is, skin color is inherited independently of other genetically controlled traits. Imagine that you are talking with a friend who knows very little about this topic. In one or two paragraphs, summarize in your own words what you have learned in this activity. Explain to your friend how skin color is one piece of evidence for the biological fallacy of race. Describe to them how skin pigment is produced and why it varies between people throughout the world.

CHAPTER OVERVIEW

15: Bioarchaeology and Forensic Anthropology

Learning Objectives

- Practice the fundamental principles needed to establish the minimum number of individuals (MNI) represented in a skeletal assemblage
- Familiarize learners with the many complex articulations in the human skull

Thumbnail: Example of activity to represent cranial articulations

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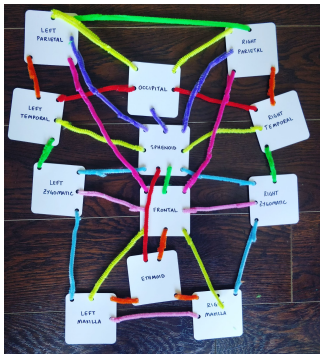
15.1: Articulating MNI in the Cranium

Articulating MNI in the Cranium

Format: In-person or online



Example of activity to represent cranial articulations

Author: Rebecca J. Gilmour

Time needed: 20-50 minutes

Supplies Needed

- Decks of cards labelled with skull bones (directions and template provided)
- Pipe cleaners
- Optional: Cranial pictures, online 3D model of a skull, or a cast of a skull (e.g. magnetic osteological teaching skull)

Readings

-
- Organ, Jason and Jessica Byram. 2019. Appendix A: Osteology. *Explorations.*

Introduction

This activity utilizes decks of homemade cards to represent cranial elements that could be found in a skeletal assemblage. Students (in groups or as individuals) analyze a unique assortment of these cards to establish the minimum number of individuals (MNI) represented in that skeletal assemblage. Students also use these cards and pipe cleaners to visually represent all the articulations and sutures in the human skull. Students will then discuss their experiences and challenges, and connect this activity to practices in bioarchaeology and forensic anthropology.

Preparation of Card Decks

- Make a variety of color coded card decks (see photo below for examples). Each color deck represents a single complete skull. The colors are a symbolic way to represent actual skeletal differences, such as differences in body size, coloration, osteological age, and preservation. To make this a little more challenging, be sure to make multiple complete skull decks in the same color (i.e., three full decks of blue). This allows students to make MNI interpretations based not only on color (easy-level), but also on duplicate elements (more challenging and more realistic).
- Within each color deck/individual skull, you will label cards with the terms below (see the template at the end of this document). Punch holes into each card to represent the total number of articulations that the bone should have (number of holes per card indicated in brackets next to the bone label).
  - Left parietal (5)
  - Right parietal (5)
  - Left temporal (4)
  - Right temporal (4)
  - Left zygomatic (4)
  - Right zygomatic (4)
  - Left maxilla (4)
  - Right maxilla (4)
  - Ethmoid (4)

- Sphenoid (9)
- Frontal (8)
- Occipital (5)

Color coded decks can be coded using different imagery, card stock, etc. Note different numbers and patterns of punched holes.

Steps

- Prior to the activity, shuffle all the decks of cards together, mixing up the multiple individuals.
- Distribute stacks of shuffled cards to groups or individuals around the class.
- First, have the students work to establish MNI.
  - This is most easily achieved by first sorting the decks by color, and next looking for duplicates within and between the colors. If, for example, there are two blue, one orange, and one green ethmoid, the MNI would be four.
- Once the groups have established their MNI, have a group discussion about their experiences and challenges. Relate this schematic exercise to practical MNI estimation on actual archaeological assemblages.
  - It is worth addressing at this point how the color coded cards oversimplify variation; discuss with the class the types of variation we might be looking for in actual archaeological assemblages (e.g. growth and development differences, body size differences, taphonomic differences).
  - Also discuss preservation: You have dealt complete skulls, what happens if only part of an element is present?
- Have the students trade cards to make complete decks for each individual. The next stage will involve refitting the skull bones to learn their complex articulations.
- Distribute pipe-cleaners to the students. Have the students use the pipe cleaners to connect the elements that would articulate in real life. Note: Students may find this easier if they keep the pipe cleaners longer with looser articulations rather than trying to create a 3D model (see photos below).
- Instruct students to identify and name each suture as it has been stylized in their cranial-spider-sculpture. They should try to first refit bones and name sutures unaided, but after attempting this, they may compare their schematic sculpture to cranial pictures (or an online 3D model) of a human skull.

Examples of articulated elements assignment. All correct articulations are depicted in the left image.

Review Questions

- Discuss your experiences with this activity. What did you learn?
- What challenges did you have with this activity?
- Would these challenges be similar with actual osteological assemblages? What additional challenges might be present? Discuss the types of variation that might be present including growth and development differences, body size differences, and taphonomic differences. Also be sure to discuss preservation and what happens if only part of an element is present.

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This exercise can be adapted for online using slides or documents.

Instructors can create text boxes (with different colored outlines or fonts) and insert the name of a specific element (e.g., Right Temporal). Students will be able to move and manipulate these text boxes, connecting them using digitally drawn lines to demonstrate articulations. For the MNI portion of the exercise, simply insert duplicates and triplicates of the same elements (remember that these should be color coded; one color = one individual) so students learn to first group and look for these multiple bone copies to establish MNI.

For Further Exploration

eSkeletons-human skull. Department of Anthropology. University of Texas, Austin. http://www.eskeletons.org/boneviewer/nid/12537/region/skull/bone/cranium

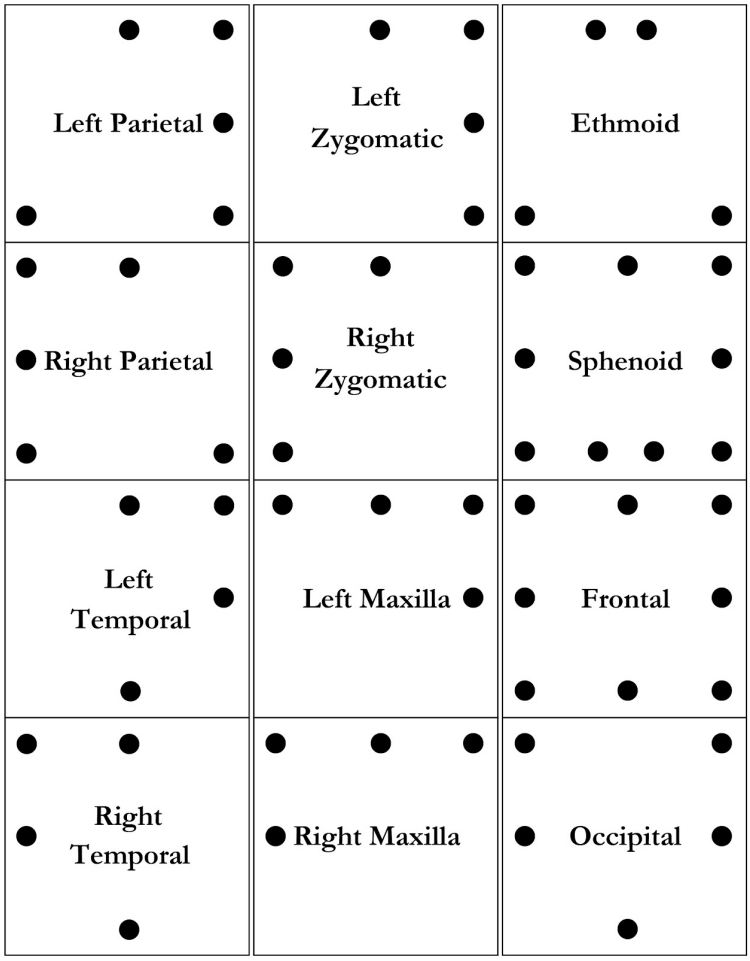
Essential Skeleton 4 App. 3D4Medical from Elsevier. (This app is a free medical app that covers the human skeleton's basic anatomy and allows users to investigate and fly through a 3D rendering of the human skeleton.)

References

Kendell, Ashley, Alex Perrone, and Colleen Milligan 2019. "Chapter 15: Bioarchaeology and Forensic Anthropology." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Organ, Jason and Jessica Byram. 2019. "Appendix A: Osteology." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions



Articulating MNI in the Cranium: Worksheet

Establish the Minimum Number of Individuals (MNI)

Consider your deck of cards. The colors are a symbolic way to represent actual bone differences, such as differences in body size, bone coloration, age, and preservation. Be aware that some individuals are not easily distinguishable by these characteristics, you may have two of the same bones in the same color!

Look for duplicate bone types in your deck of cards. What is the *minimum* number of individuals that must be present? For example, every individual will have one right parietal bone. If TWO right parietal bones are present, there must be *at least* two individuals represented (i.e., MNI = 2).

Think about the challenges you encounter during this exercise. Imagine what it would be like to estimate MNI on an actual archaeological collection. What would be different doing this on real bone? How might your estimate be limited? Is it realistic to think we can easily divide elements by individuals, as you have just done by color?

Spider-Skull: Refitting the Articulations:

Sort your cards into single-individual decks. Work together as a class team to trade skull element cards so everyone has a complete deck. Your deck should consist of a single color and one card for each of following bone types:

- Left parietal
- Right parietal
- Left temporal
- Right temporal
- Left zygomatic

- Right zygomatic
- Left maxilla
- Right maxilla
- Ethmoid
- Sphenoid
- Frontal
- Occipital

Think about how the skull bones connect to and articulate with each other. Apply your understanding of these cranial articulations and sutures to connect the bones using pipe cleaners. Holes have been punched in each card to represent the total number of articulations each bone should have. Test your memory by trying to articulate the cards first before consulting an image of a skull.

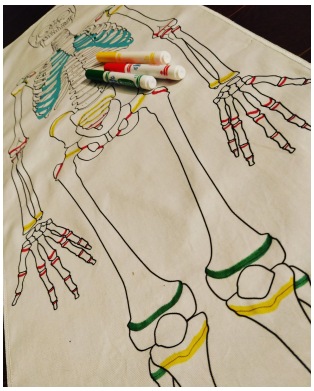
Note: Do not connect the cards too tightly (short pipe cleaners). This will likely not give you enough room to work in all the articulations. It is not necessary to connect the elements in a 3D manner, you may first wish to plan your arrangement by laying the cards out on a table.

Once you have reconstructed your cranium, review the articulations by naming each suture that they correspond to. Test yourself and quiz your peers.

15.2: Roll-Up, Life-Sized Juvenile Age Estimation

Roll-Up, Life-Sized Juvenile Age Estimation

Format: In-person or online



Author: Rebecca J. GilmourFabric skeleton with color coded epiphyses

Time needed: 15 minutes - 2 hours[1]

Learning Objectives

- Observe various patterns in epiphyseal fusion
- Read ossification and fusion charts in order to estimate the most likely age-range of each individual.
- Think critically about how age at death is estimated from juvenile (subadult) skeletons,
- Identify limitations and challenges of estimating MNI in archaeological or forensic contexts.

Supplies Needed

- Fabric/paper skeleton prints with color coded epiphyses (image attached)
  - Some individuals can be supplemented with other information (e.g., hand x-rays, plastic skeletal casts, see below)
- Blank fabric/paper skeleton print
- Washable colored markers
- Epiphyseal fusion and dental development charts
- Graph paper

Readings

- Kendell, Ashley et al. 2019. Chapter 15: Bioarchaeology and Forensic Anthropology. *Explorations*.
- Organ, Jason and Jessica Byram. 2019. Appendix A: Osteology. *Explorations.*

Introduction

This activity aims to get learners thinking critically about how age at death is estimated from juvenile (subadult) skeletons. It uses skeletal images printed on paper or cloth, and then the metaphyses or epiphyses are colored (to represent ossification/fusing), so that students can evaluate to estimate skeletal age. In Part 1, students estimate the age of a pre-prepared individual. In Part 2, students will apply what they have learned to create their own growth and development templates. Finally, they should present their observations and discuss any limitations and difficulties they encountered.

Steps

Preparation of Materials

This activity requires the instructor to print illustrations of a sub-adult skeleton marked with colored pens to indicate skeletal ossification and fusion. A template for the subadult skeleton is found at the end of this activity guideline and can also be retrieved from rebeccagilmour.ca.

One option is to print the skeletal illustration on fabric. The author (Gilmour) had hers printed life-sized on lightweight cotton twill fabric via spoonflower.com. If washable markers are used on the fabric, the skeleton prints are (theoretically) able to be cleaned

and reused. The images can also be printed on paper; if laminated, dry erase markers can make the templates reusable. While it is not necessary to print the skeleton diagram as life-sized, doing so will make the exercise feel more authentic.

For Part I of the exercise, the instructor must decide what approximate ages they would like each skeleton to depict. Using skeletal fusion charts and information (such as provided by Scheuer and Black 2000), color in the metaphysis or epiphysis to indicate if the element is not yet ossified, unfused, fusing, or fused. Suggested color codes are:

Purple = Not Yet Ossified
Green = Unfused
Yellow = Fusing
Red = Fused

Each skeletal diagram should be supplemented using freely-available dental and hand radiographs from the Burlington Growth Study; available online at: https://www.aaoflegacycollection.org/aaof_collection.html?id=UTBurlington.

Student will also need to be provided and shown how to use epiphyseal fusion and dental development charts, such as those from White and Folkens (2005) and Scheuer and Black (2000).

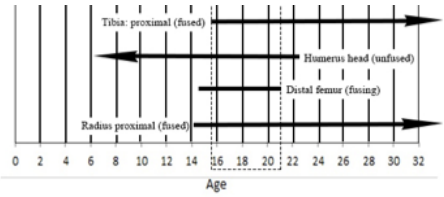
Part 1: Estimate the Age of Pre-Prepared Juveniles

- Distribute color-coded skeletal illustrations (and supplementary radiographs) to students or small groups of students.
- Have students work in groups to observe each epiphysis and element. In consultation with epiphyseal ossification and fusion charts and dental development diagrams, ask students to record each attribute, the state of fusion, and their age estimation for that specific element, epiphysis, or observation using a table (see example below).

Example of a table to record observations alongside their associated age interpretations.

Epiphysis	State of Fusion	Age Interpretation (years)
Proximal humerus (head)	Unfused	<20
Distal radius	Fusing	14-20
Proximal Ulna	Fused	>12

- Next, ask students to visualize the overall age-estimation by plotting each age range for each growth and development observation on graph paper (see figure below).
- Students should label the x-axis with age and plot each age range for each point of fusion/development along the y-axis. Students should be reminded to always report age ranges in osteological assessments, as there is some error associated with these methods (some individuals will fuse earlier or later than others)



Plotted age-estimations with area of greatest age overlap indicated with a dotted line. See White and Folkens (2005: 373, Fig. 19.6) for similar fusion charts.

- Using the chart they have created, students should look for the region of greatest age overlap. The area of greatest overlap is indicated by dotted lines in the figure above.
- Once students have estimated the age of the individual at one station, they should cycle through stations until they have estimated all the ages of all the stations the instructor created.

Part 2: Create Your Own Sub-Adult

- In this stage of the exercise, students will apply what they have learned to create their own growth and development templates (these may be used by the instructor in future iterations of the course and activity).
- Provide students with a completely blank sub-adult poster/canvas. Secretly assign them an age at death for their specific individual. You may choose to put ages on slips of paper and have students draw these at random.

- Students should refer to the charts in White and Folkens (2005) and Scheuer and Black (2000) to color in the epiphyses that would be not ossified yet, unfused, fusing, or fused. They should adhere to the same color scheme as the instructor:

Purple = Not Ossified Yet!
Green = Unfused
Yellow = Fusing
Red = Fused

- Have students illustrate and indicate an appropriate pattern of dental development and eruption. Be able to discuss what you would expect to observe on their individual's dental radiograph.
- Once students have completed their growth and development schematics, have them trade their work with a neighboring group. Time the groups to see who can estimate the age fastest while obtaining the most accurate age estimation. At the instructor's discretion, the fastest and most accurate group could win a prize.

Conclusion

- At the end of each exercise, have students briefly present their observations.
- Check with the students to talk about the limitations and difficulties they encountered. Be sure to discuss how this stylized activity may differ from actual analysis of archaeological human bone.
- Discuss limitations to age-estimation techniques as they relate to preservation and collection/curation complications. For example, you may ask the class: "What if none (or only some) of the epiphyses were collected during excavation? How would the anthropologist know they were missing (as opposed to not ossified)? Could the anthropologist still estimate the age of the individual?"

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

This activity can easily be adapted for online use by providing students with a small library of digitized skeleton diagrams (supplemented as needed using images from the Burlington Growth Study). The instructor may wish to print, color, and scan images to be sent to students. Students can independently estimate skeletal age, and using LMS discussion forums or Google Docs, critically discuss their estimated ages with each other. Students can also generate their own growth and development diagrams to share and test each other in these forums.

For Further Exploration

The University of Toronto Burlington Growth Study (includes craniofacial and hand/wrist images) https://www.aaoflegacycollection.org/aaof_collection.html?id=UTBurlington

J-Skel The Digital Age Estimator of Subadult Skeletons http://j-skel.matrix.msu.edu/

References

The University of Toronto Burlington Growth Study. https://www.aaoflegacycollection.org/aaof_collection.html?id=UTBurlington

Kendell, Ashley, Alex Perrone, and Colleen Milligan 2019. "Chapter 15: Bioarchaeology and Forensic Anthropology." In Explorations: An Open Invitation to Biological Anthropology, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Life Size Printout, Juvenile, Modern Homo sapiens. eSkeletons.org http://eskeletons.org/sites/eskeletons.org/files/files/resources/000646791.pdf

Organ, Jason and Jessica Byram. 2019. "Appendix A: Osteology." In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Scheuer, Louise and Sue Black. 2000. *Developmental Juvenile Osteology.* San Diego: Elsevier.

White, Tim D. and Pieter A. Folkens. 2005. *The Human Bone Manual.* San Diego: Elsevier Academic Press.

Image Attributions

Roll-Up, Life-Sized Juvenile Age Estimation Worksheet

Part 1: Estimate the Age of Pre-Prepared Juveniles

1. On each skeleton, a series of epiphyses have been color coded according to their degree of fusion:

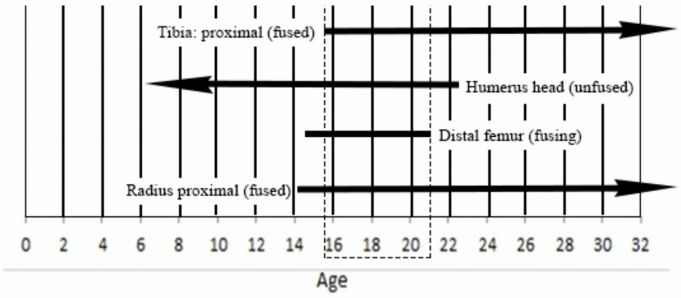
Purple = Not Ossified Yet!
Green = Unfused
Yellow = Fusing
Red = Fused

2. Observe each epiphysis and consult the epiphyseal ossification and fusion charts and dental development diagrams in White and Folkens (2005) and Scheuer and Black (2000). Then create a table to help you record your observations and age ranges. An example table is provided below. Please create yours at the top of a sheet of graph paper.

Example of a table to record observations alongside their associated age interpretations.

Epiphysis	State of Fusion	Age Interpretation (years)
Proximal humerus (head)	Unfused	<20
Distal radius	Fusing	14-20
Proximal Ulna	Fused	>12

3. Observe the pattern of dental development and eruption for each individual. Consult dental development/eruption charts in White and Folkens (2005). Which pattern of development and eruption does your individual best match? Record the age range in your table (on the graph paper).
4. Visualize your age-estimations by plotting the age range for each element's fusion and the dental development pattern on a chart using the graph paper, similar to that of the figure below. Be sure to label your x-axis with age and plot your age range interpretations for each observation along the y-axis.
5. Find the area of the greatest age overlap in your chart. This range is your individual's best estimated age at death. The area of greatest overlap is indicated by dotted lines in the figure below. Remember to always report age ranges in osteological assessments, as there is some error associated with these methods (some individuals will fuse earlier or later than others). What is your estimated age at death range?



Plotted age-estimations with area of greatest age overlap indicated with a dotted line. See White and Folkens (2005: 373, Fig 19.6) for similar fusion charts.

Part II: Create Your Own Sub-Adult

1. On a blank sub-adult poster, use the colored markers to create a fusion pattern consistent with the osteological age range your instructor secretly assigned you.

Age Assigned By Instructor: _____

Indicate your fusion/ossification patterns using the following colors:

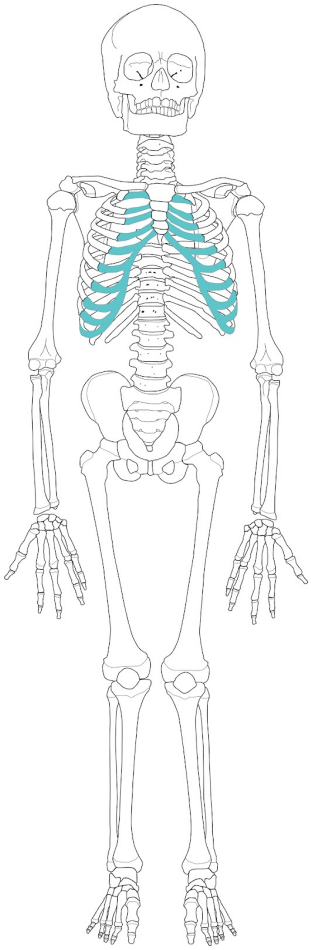
Purple = Not Ossified Yet!
Green = Unfused
Yellow = Fusing
Red = Fused

2. Illustrate and indicate an appropriate pattern of dental development and eruption. Be able to discuss what you would expect to observe on your individual's dental radiograph.
3. Trade your sub-adult poster with a neighboring student/group. Test yourselves: see who can estimate the age the fastest, while remaining accurate!

Conclusion: Present your Observations and Discuss

1. How old was your individual? Tell your classmates why you estimated the age range as you did.
2. What limitations and difficulties did you encounter?
3. How might this stylized activity differ from actual analysis of archaeological human bone? Discuss limitations to age-estimation techniques as they relate to preservation and collection/curation complications.

Juvenile Skeleton



1. The time required for this activity varies depending on the combination of components observed. The activity can range from 15 minutes (one individual from Part I) to 2 hours (multiple individual observations from Part I, creation of an individual in Part II, and a final discussion).

CHAPTER OVERVIEW

16: Contemporary Topics- Human Biology and Health

Learning Objectives

- Analyze aspects of the human cardiovascular and endocrine systems in relation to evolution and contemporary health issues.

Thumbnail: Banksy’s Caveman by Lord Jim

16.1: Stone Age Bodies, Space Age Challenges

Stone Age Bodies, Space Age Challenges

Format: In-person or online

Banksy's Caveman by Lord Jim

Author: Joylin Namie, Ph.D.

Source: Modified from Human Anatomy & Biological Systems Laboratory Experience, Anthropology 110L, Truckee Meadows Community College

Time needed: 60 - 75 minutes

Supplies Needed

- Blood pressure wrist cuff [optional]
- Measuring tape
- Internet access

- Readings
-

16.2: Global Distribution of BMI

Global Distribution of BMI

Format: In-person or online

Body Mass Index categories

Author: Nelson, Katie

Time needed: 40-60 minutes

Learning Objectives

- Chart and analyze global BMI data.
- Identify trends in global BMI data.
- Calculate one's own BMI and relate it to larger global and national trends.

Supplies Needed

- Scale and measuring tape
- Worksheet (provided)
- Graphing software or PowerPoint

Readings

-

Introduction

In this activity, students use global Body Mass Index (BMI) data compiled by the World Health Organization (WHO) to create a chart that represents the average (mean) BMI for multiple countries from 1975 to 2015. Students also calculate their own BMI and relate it to larger global and national trends.This activity prompts students to reflect on the relationship between one's environment and biology in determining health.

Steps

1. Students will weigh themselves and measure their height, documenting these data in pounds and feet/inches.
2. Using the National Institute of Health BMI calculator, students calculate their own BMI.
3. Students select six countries to track. They then access these countries, using WHO data and list the percentage of each country's population that have a BMI of 30 or greater by year.
4. Using a charting software or PowerPoint chart feature, students input the BMI data from all of their six countries into a single chart, including data from 1975, 1985, 1995, 2005, 2015. They then project what the BMI will be for each country in 2025.
5. Students analyze the data, discuss trends, and hypothesize why there are differences between countries and changes over time.
6. Students reflect on their own BMI in relation to country trends.

Review Questions

- Why do BMI differ so much from country to country?
- What could be the causes of the progressive increase in BMI in most countries since 1975?
- Who benefits from the global obesity epidemic? Think about the following industries and institutions: How might the medical establishment profit from obesity? The fitness industry? The diet industry? Fashion? Pharmaceutical companies? Food manufacturers? Advertisers?

Tips and Suggestions

Some students may be uncomfortable disclosing their weight and height. If this is the case, you may wish to modify this activity. One way to do so is to allow students to omit their own raw BMI data and instead only answer the questions in which they reflect on their BMI as it compares to national data and in general, rather than specific, terms.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

- The World Most Obese Nations by Animated Stats: https://www.youtube.com/watch?v=nvJsEX9MWpw
- Watch the World Become Obese: https://www.youtube.com/watch?v=jMqxTuoWqsQ

References

Namie, Joylin. 2019. “Chapter 16: Contemporary Topics: Human Biology and Health.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

World Health Organization (WHO). 2017b. “Obesity and Overweight.” Fact Sheet. Last modified October 2017. http://www.who.int/mediacentre/factsheets/fs311/en/.

Image Attributions

Women Body Mass Index by unknown is in the public domain.

Global Distribution of BMI Worksheet

According to the World Health Organization (WHO), more than two billion people throughout the world are overweight or obese, which is defined as having a body mass index (BMI) over 30. As Joylin Namie notes in chapter 16, “for the first time in human history, most of the world’s population lives in countries where overweight and obesity kill more people than hunger does.” Of course, the causes for these growing rates of obesity are as complex as the problems obesity causes. Some causes include a sedentary lifestyle, overeating and eating processed and calorie dense foods. In this activity, you will access data from the WHO on BMI percentages and track changes in BMI over time in six countries.

Step One: Calculate Your BMI

Using a scale and measuring tape, weight yourself and measure your height. Document your personal data on a note card or scrap of paper. If you wish, you may include your data below, however this is not required if you are not comfortable disclosing this information. Be sure to indicate standard or metric measurements.

Weight _____ pounds / kilograms

Height _____ feet & inches / centimeters

Now, navigate to the National Institute of Health’s online BMI calculator. Input your height and weight data into the calculator and document your BMI score in the space below. You can also calculate your BMI using this chart.

Total BMI_____

Which category does your BMI fall into (see chart below)? _____

BMI	Category
<18.5	Underweight
18.5–24.9	Normal weight
25–29.9	Overweight
30 or greater	Obesity

Step Two: Document Global BMI Data

Navigate to the WHO's interactive global obesity atlas and select six countries you wish to document. Type the names of each country into the country heading in the table below. Then, within the atlas, click on the "view by sex/year" lab at the top left, select "Both sexes", scroll down to 1975 and click on that year. This will display the average (mean) BMI for each country in 1975. Using your computer mouse, hover the arrow over each of the countries you have selected and then type in the percentage for each country. Continue this process for each year in the chart and for each country.

BMI Data for Select Countries

	Country 1	Country 2	Country 3	Country 4	Country 5	Country 6
1975						
1985						
1995						
2005						
2015						

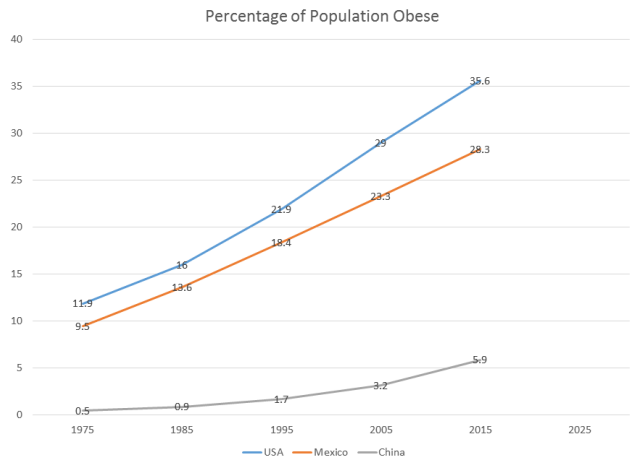
Step Three: Graph the Data

Next, using a graphing software or the graphing feature in google docs or PowerPoint, create a line graph with all six countries. In addition to data points for 1975, 1985, 1995, 2005 and 2015, add a space on the graph for 2025 (but with no data). Be sure the names of the countries and the data points (numbers) are labeled and clear. Your graph will look something like the one below, except with six data sets, not three. Give your chart a title and copy and paste it in the space below the example chart.

Line graphing tutorials:

- For a tutorial on how to create a line graph in google docs, click here.
- For a tutorial on how to create a line graph in Microsoft PowerPoint, click here.

Example Chart



Paste your chart in the space below.

Step Four: Analyze the Data

Study the chart you created carefully and make an educated guess what the average BMI will be for the countries in your chart for the year 2025. Add these numbers to the table below. Don't forget to change the country names to the ones in your data sets. Then, answer the questions below.

BMI Estimate for 2025

	Country 1	Country 2	Country 3	Country 4	Country 5	Country 6
2025						

1. What happened to the BMI data in your chart from 1975 to 2015? Was it the same for all countries in your chart?
2. Based on what you learned in chapter 16, explain why you think the trends you noted in your chart occurred. What accounts for the similarities or differences between the countries?
3. What do you think are the global consequences for all humans of these trends?

Step Five: Wrap-up

Return to the WHO interactive atlas and locate the most recent BMI percentage for the country where you currently live. Then answer the questions below.

4. How does your BMI (from Step 1) compare with the most recent average for your country? Why do you think your BMI is the same or different from the average?
5. If you lived in a different country, one with a different average BMI, do you think over time your BMI would become similar to that country's average? Explain.
6. Which do you think more strongly influences your own health, your environment or your inherited biology? Explain.

CHAPTER OVERVIEW

17: Appendices

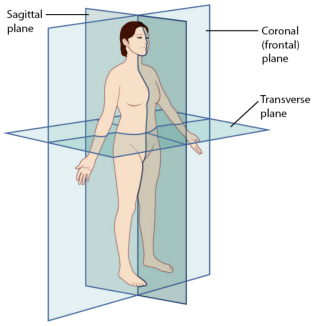
17.1: Appendix A- Osteology - Directional Terms

Learning Objectives

- Learn terms for anatomical planes and directional terms used in osteology
- Practice using directional terms to refer to familiar body parts

Directional Terms

Format: In-person or online



The three planes most commonly used in anatomical and medical imaging are the sagittal, frontal (or coronal), and transverse planes.

Author: Alex Perrone and Beth Shook

Source: Adapted from Anatomical Terms Worksheet BIO 250. BOOST Consortium, Wallace Community College Selma, and used under a CC BY 4.0 License.

Time needed: 20-30 minutes

Supplies Needed

- Student worksheet (attached)

Readings

- Organ, Jason and Jessica Byram. 2019. Appendix A: Osteology. *Explorations.*

Introduction

This brief assignment introduces students to osteology by allowing them to learn and practice using anatomical terms.

Steps

- Introduce the concept of directional terms and how they are used in both osteology and anthropology.
- Go over the names of specific anatomical planes, paired directional terms, and anatomical regions (e.g. cranial and post-cranial)
- Students can work through the worksheet independently or in pairs.

Conclusion

When students have completed their worksheets, play a game to see how well they have learned the terms. For example, the class can play a game of “Simon Says”. For Simon says, the instructor can say “Simon says to draw the __ plane in the air” or “Simon says to indicate ‘lateral’” by pointing. Students who illustrate the wrong directional term or who draw/point to something when Simon didn’t say so, will be out of the game.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be(mark in bold):

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

These worksheets can be done individually or in pairs, face-to-face or virtually. If you want to do the activity synchronously, students could work in pairs or groups of three to fill out copies of a Google Doc or Google Slides. For the conclusion, Simon Says could be played synchronously with video on.

For Further Exploration

Essential Skeleton 4 App. 3D4Medical from Elsevier for the iPad or iPhone.

Get Body Smart. https://www.getbodysmart.com/skeletal-system

References

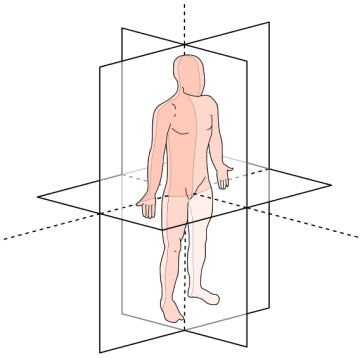
Organ, Jason and Jessica Byram. 2019. “Appendix A: Osteology.” In *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Image Attributions

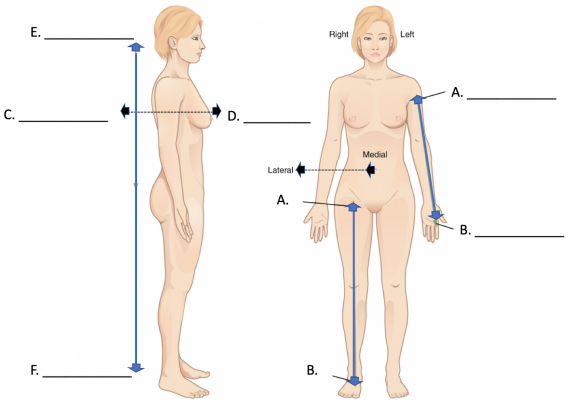
Directional Terms

Label the Diagrams

Label the three anatomical planes below. Then label the dotted line that divides the body into equal right and left halves.



Label the letters A through F on the diagram below with the corresponding directional terms. Please note that A and B are on the chart twice but only need to be labeled once.



Word Match

Write in the term that best corresponds with the definitions in the table. Select terms from the word bank below.

Anterior Lateral Proximal

Cranial Medial Superior

Distal Postcranial

Inferior Posterior

Anatomical Term	Definition
	Away from the body, along a limb
	Pertaining to all of the skeleton except the skull
	Towards the top, or above
	Pertaining to the head
	Towards the body, along a limb
	Back, or at the back of
	Towards the bottom, or below
	Away from the midline of the body
	Front, or in front of
	Toward the midline of the body

Draw a line between terms in the two columns to match the paired terms.

Proximal Distal

Medial Inferior

Anterior Posterior

Superior Lateral

Complete the Sentence

Complete these sentences using the terms **superior** and **inferior**.

The nose is _____ to the forehead.

The sternum is _____ to the belly button.

The head is _____ to the body.

Complete these sentences using the terms **anterior** and **posterior**.

The heel is _____ to the toes.

The belly button is _____ to the spine.

The clavicle (collarbone) is _____ to the scapula (shoulder blade).

Complete these sentences using the terms **lateral** and **medial**.

The arms are _____ to the midline.

The neck is _____ to the shoulders.

The hips are _____ to the belly button.

Complete these sentences using the terms **proximal** and **distal**.

The fingers are _____ to the elbow.

The knee is _____ to the foot.

The wrist is _____ to the shoulder joint.

17.2: Appendix B- Primate Conservation

Primate Conservation

Format: In-person or online

Bonnet macaques (*Macaca radiata*) being fed by tourists.

Author: Lara Braff

Time needed: 90-120 minutes

Learning Objectives

- Describe threats to nonhuman primates
- Research an endangered nonhuman primate species
- Develop a public-facing conservation poster for the selected species

Supplies Needed

- Access to internet
- Student worksheet

Readings

- Dinsmore, Mary, et al. 2019. Appendix B: Primate Conservation. *Explorations.*

Introduction

As described in Appendix B of *Explorations*, many nonhuman primate populations are negatively impacted by anthropogenic activities, such as hunting, poaching, deforestation, and global warming. Extinction now threatens over half of all nonhuman primates and three-fourths of primate species face population decline (Dinsmore, et al. 2019). This has dire consequences for all living species due to the essential role that primates play within their local ecologies. As nonhuman primates are our closest living relatives, we humans have a unique obligation to protect them.

In this activity, students will select an endangered primate species, conduct research on it, and then create a public-facing poster to inform laypeople about the species and how to protect it. This project can be completed outside of class time and then students can present their posters in class.

Steps

- This project can be done individually or in groups, and completed in-person or online.
- Students will select an endangered nonhuman primate species to research.
- Students will research the species, its ecology, threats to its survival, and steps humans can take to protect it.
- Students will develop a poster, intended for the general public, that clearly communicates the ecological significance of the species and conservation strategies.
- Posters may be displayed in class or on the course site.

Review Questions

1. What are some anthropogenic causes of nonhuman primate endangerment and extinction?
2. What are the most impactful ways humans can protect nonhuman primate species?
3. Discuss nonhuman primate conservation efforts and their importance.

Adapting for Online Learning

If this is an in-person lab, rank how adaptable to online learning it would be (mark in bold):

Tip: For online courses, students can create a poster to display on the course page.

References

Dinsmore, Mary P., Ilianna E. Anise, Rebekah J. Ellis, Amanda J. Hardie, Jacob B. Kraus, and Karen B. Strier. 2019. “Appendix B: Primate Conservation.” In *Explorations: An Open Invitation to Biological Anthropology,* edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Global Wildlife Conservation. https://www.globalwildlife.org/project/primates/

International Union for the Conservation of Nature (IUCN) Red List. https://www.iucnredlist.org/search?taxonomies=100091&searchType=species

Primate Specialist Group of the IUCN. http://www.primate-sg.org

Wisconsin National Primate Research Center. https://primate.wisc.edu/primate-info-net/

Image Attributions

Primate Conservation Worksheet

Instructions

In this activity, you will conduct research about a nonhuman primate species that faces the threats of endangerment or extinction. Many of these threats are anthropogenic (human originated) ones, such as hunting, poaching, deforestation, and global warming. To select a species, refer to the IUCN Red List (link below) or Appendix B. After selecting a species, you will conduct web-based research, focusing on:

1. the species’ main physical and behavioral characteristics;
2. its habitat and role(s) within the local ecology;
3. specific anthropogenic threats to its survival;
4. steps humans can take to protect the species.

Based on this research, you will create a public poster that clearly communicates information about the species, its ecological niche, its endangerment, and what humans can do to help. Your poster should be visually appealing and understandable to a layperson.

The following websites are useful starting points for your research:

International Union for the Conservation of Nature (IUCN) Red List. Search this site by the Order (Primate) and select a species to learn about the population, habitat and ecology, threats, and conservation actions.

- https://www.iucnredlist.org/search?taxonomies=100091&searchType=species

The IUCN Primate Specialist Group is comprised of primatologists and conservationists. Their website houses useful resources about endangered nonhuman primates. “Primates in Peril” (found under “Special Reports”) includes past and current reports about the most endangered species.

- http://www.primate-sg.org
- http://www.primate-sg.org/special_reports/

Wisconsin National Primate Research Center: Primate Info Net. This website provides links to research about nonhuman primates and conservation efforts. The “Primate Factsheets” include information about specific species and their evolution, ecology, behavior, and conservation status.

- https://primate.wisc.edu/primate-info-net/
- https://primate.wisc.edu/primate-info-net/pin-factsheets/

Global Wildlife Conservation is dedicated to research and activism to preserve wildlands and wildlife. A section of its website focuses on endangered nonhuman primates, particularly the red colobus monkeys, lemurs of Madagascar, and Atlantic Forest

primates of Brazil.

- https://www.globalwildlife.org/project/primates/

17.3: Appendix C- Human Behavioral Ecology - The Evolution of Cooperation

The Evolution of Cooperation

Format: In-person or online

Authors: Herzog, Nicole; Snopkowski, Kristin

Modified from: The Game of Trust www.ncase.me/trust

Time needed: 75 minutes

Learning Objectives

- Define the Prisoner's Dilemma game
- Identify the most successful strategy in a one-shot prisoner's dilemma game and an iterated prisoner's dilemma game
- Identify factors that can break down cooperation or trust
- Explain how the Prisoner's Dilemma game can help us understand human food sharing

Supplies Needed

- Internet access
- Worksheet (provided)

Readings

-

Introduction

The Prisoner's Dilemma game is a hypothetical game where two players have the option to *cooperate* with each other or *cheat*, without knowing what the other player will do. It is based on a situation where two people are arrested for a crime (hence: prisoner's dilemma). If they both keep silent, meaning that they do not tell the police what they did and cooperate with their partner, each gets limited jail time (let's say, one year). But if one cheats, by telling the police, and the other one cooperates, by staying silent, then the one who cheats does not go to jail and the one who cooperates gets a long sentence (let's say, three years). If both players cheat, by telling the police, then both individuals do a moderate sentence (two years). This game has been used extensively to understand when individuals will cooperate and when they will cheat. In this lab, we will use the prisoner's dilemma game (also known as the Game of Trust) to understand which strategies (cheating or cooperating) are best, given particular circumstances, providing insights into the evolution of cooperation. After playing the game, students reflect on how this helps us understand human food sharing behavior.

Game theory is defined as the study of the ways in which interactions among players produce outcomes. In this case, students play the Game of Trust. Their payoffs are in terms of coins. Each student is represented by the player on the left (the character with the red hat) and they play with a 'computer player'. If the student cooperates and the computer player cheats, the student loses a coin. If both cooperate, the student earns two coins. If the student cheats and the computer player cooperates, the student earns three coins. If they both cheat, the student earns zero. If the student plays the game once, it's known as a *one-shot prisoner's dilemma* game.

Steps

1. Students navigate to: www.ncase.me/trust. It is best if each student has their own device to play.
2. Let students know that there is a set of circles on the bottom of the screen, if students need to move to another part of the game, they can use the circles to move quickly to the end or beginning of the game. They won't be marked down for their choices of play in the game. They will only be evaluated based on their answers to the accompanying questions.
3. Distribute the worksheet and tell students to read the instructions step-by-step as they play and then answer the questions in order.
4. After they play, discuss the reflection questions and make connections with how this game can help understand human food sharing.

Reflection Questions

While the Prisoner's Dilemma game was not designed to explain food sharing, we can use the game to help us understand the dynamics of trust and cooperation as they relate to decisions about resource sharing within small-scale societies.

1. Thinking about the Prisoner's Dilemma game, which factors would you expect to see in a population that engages in extensive food sharing?
2. Which factors are we unable to account for in the Prisoner's Dilemma game and how might that limit its application to the problem of food sharing?

Adapting for Online Learning

1 Not adaptable 2 Possible to adapt **3 Easy to adapt**

For Further Exploration

- Radiolab: Tit for tat https://www.wnycstudios.org/podcasts/radiolab/segments/104010-one-good-deed-deserves-another
- Henrich, Natalie; Henrich, Joseph, 2007. *Why Humans Cooperate: A Cultural and Evolutionary Explanation.* Oxford: Oxford University Press Inc.
- Tomaselloby, Michael; Dweck, Carol. 2009. *Why We Cooperate*. Massachusetts: The MIT Press

References

Henrich, Natalie; Henrich, Joseph, 2007. *Why Humans Cooperate: A Cultural and Evolutionary Explanation.* Oxford: Oxford University Press Inc.

Snopkowski, Kristin. 2019. "Appendix C: Human Behavioral Ecology". *Explorations: An Open Invitation to Biological Anthropology*, edited by Beth Shook, Katie Nelson, Kelsie Aguilera, and Lara Braff. Arlington, VA: American Anthropological Association. http://explorations.americananthro.org/

Tomaselloby, Michael; Dweck, Carol. 2009. *Why We Cooperate*. Massachusetts: The MIT Press.

Image Attributions

Acknowledgement

Thanks to Nicky Case for developing The Game of Trust interactive website.

The Evolution of Cooperation Worksheet

The Prisoner's Dilemma game is a hypothetical game where two players have the option to *cooperate* with each other or *cheat*, without knowing what the other player will do. It is based on a situation where two people are arrested for a crime (hence: prisoner's dilemma). If they both keep silent, meaning that they do not tell the police what they did and cooperate with their partner, each gets limited jail time (let's say, one year). But if one cheats, by telling the police, and the other one cooperates, by staying silent, then the one who cheats does not go to jail and the one who cooperates gets a long sentence (let's say, three years). If both players cheat, by telling the police, then both individuals do a moderate sentence (two years). This game has been used extensively to understand when individuals will cooperate and when they will cheat. In this lab, we will use the prisoner's dilemma game (also known as the Game of Trust) to understand which strategies (cheating or cooperating) are best given particular circumstances, providing insights into the evolution of cooperation.

After playing the game, you will reflect on how this helps us understand human food sharing.

Getting Started

On your preferred device, navigate to: www.ncase.me/trust. Carefully read and follow the directions. Play the first two rounds of the game and then answer the following questions.

1. When the other player *cheats*, what option (cheat or cooperate) gives you the best payout?
2. When the other play *cooperates*, what option (cheat or cooperate) gives you the best payout?
3. Explain why this is a "dilemma."

Iterated Game of Trust

Now play the *repeated* or *iterated* game, where you play against five different opponents and each has their own strategy.

4. How many total coins did you earn against the five different opponents? (Note: This may take several minutes to play each set of games)
5. How did you decide whether to cheat or cooperate in these rounds?
6. We now learn that each of the opponents has a strategy. In the chart below, describe the five strategies that you played against. The strategy *copycat* is also known as "tit for tat."

Name	Describe Strategy	Hat Type
Copycat		
All cooperate		
All cheat		
Grudger		
Detective		

7. Which character do you think will be most successful in a tournament where each player plays all others? Describe your reasoning.
8. Place your bet by choosing the character you think will win. Observe the results of the repeated games. Did your character win? If not, which character won?
9. What conditions occurred during World War I trench warfare that allowed for peace?

Evolution

Human Behavioral Ecologists are interested in the evolution of behavior. Specifically, they seek to learn how trust and cooperation evolved, particularly when there is an advantage to cheating. Let's observe how things change when our characters are allowed to evolve – meaning that successful players reproduce and unsuccessful players are eliminated.

10. Describe how this relates to the concept of Natural Selection.
11. Who do you think will win the *first* tournament (of Copycat, All Cooperate, and All Cheat)? Explain your reasoning.
12. What happens when you have *All Cooperate* and *All Cheat* in the same tournament?
13. Which strategy "inherits the earth" or becomes the only strategy remaining after many rounds of the tournament?
14. Now add Grudger and Detective back in: Which strategy "inherits the earth"?

The Evolution of Distrust

Now we will change the game to adjust the number of rounds our characters play. In the table below, document which strategy wins under each of these conditions.

Number of Rounds	**Winning Strategy**
10	Copycat
7	
5	
3	

1	

15. Explain why the winning strategy changes at fewer numbers of rounds.
16. What happens when the “both cooperate” payoff is changed from +2 to +1? Note: You need to adjust the payoff values and then click “Start”.
17. Explain why this changes the optimal strategy.
18. What happens if you change the payoff for cooperation by increasing its value?
19. What is a “Zero-sum Game” and a “Non-Zero-Sum Game”? Why does it matter if you are playing a zero-sum versus. non-zero sum game?

Mistakes

20. How can honest mistakes affect the game?
21. Click “…deal with mistakes” In the table below, describe the new strategies.

Name	Describe Strategy	Hat Type
Copykitten		
Simpleton		
Random		

22. Who do you think will win if they play in a tournament? Explain your reasoning.
23. Who do you think will win if the population of players includes *All Cheat* instead of *All Cooperate*? Explain your reasoning.
24. Now we can adjust the frequency of mistakes to see if that influences the best strategy for a population that includes *All Cheat*. Fill out the following table:

Percent of Miscommunication (or mistakes)	**Winning Strategy** (Note: This strategy may change depending on the randomness in the simulation. Also, it’s possible for two strategies to remain)
5%	Copykitten
0%	
1%	
10%	
25%	

Optional: Sandbox Mode

If you would like, you are welcome to play in the sandbox mode to further understand how different starting populations, payoffs, and rules influence winning strategies.

Conclusion

25. Based on this activity and the reading, name and describe three key issues impacting the evolution of altruism and trust?

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Glossary

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