EDUCATOR GUIDE

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Attn: Reservations

PerotMuseum.org/FieldTrips

Perot Museum of Nature and Science

FIELD TRIP INFORMATION

Origins: Fossils from the Cradle of Humankind exhibition plus access to our 11 state-of-the-art permanent exhibit halls. For more information about field trips, please contact us at 214.428.5555 ext. 8 or reserve@perotmuseum.org.

Before you visit the *Origins* exhibition:

- Do some preparation activities before your visit.
- Review this guide for connections to your curriculum. Choose the activities that best meet your needs. Jigsaw groups to provide fewer questions for each student, but still cover topics you need.
- Add your own page(s). Use journals or composition notebooks if you use these in classroom work. Bring sturdy cardboard to write on if you plan to use single pages during your field trip.
- Share expectations, plans, and schedules for the visit with students and chaperones. Give chaperones copies of any activities students will do.
- Encourage students to spend time in *Origins* beyond simply answering questions.

During your visit to the *Origins* exhibition:

- Ask students to add their own questions and observations that arise during their exhibition explorations.
- Students must be with their chaperones to enter the exhibition, and should stay with the chaperone throughout.
- Divide your class into small groups to work together in the exhibition.

DON'T MISS THIS COMPLEMENTARY MUSEUM PROGRAM

HOMINID LAB (GRADES 6–8)

Learn to think like a paleoanthropologist! In this lab, students will learn about the methods scientists use to identify and date fossils. They will also examine fossil models to uncover the adaptations of various early human relatives.

MUSEUM EXHIBITS

While on your field trip, be sure to stop by the *Being Human Hall* on Level 2 to further enhance your human journey experience.

Your students will explore the traits and abilities that are essential and unique to being human – from early origins and DNA; to the complexities of the brain, hands, face, and voice; to the miracle of movement.

TABLE OF CONTENTS

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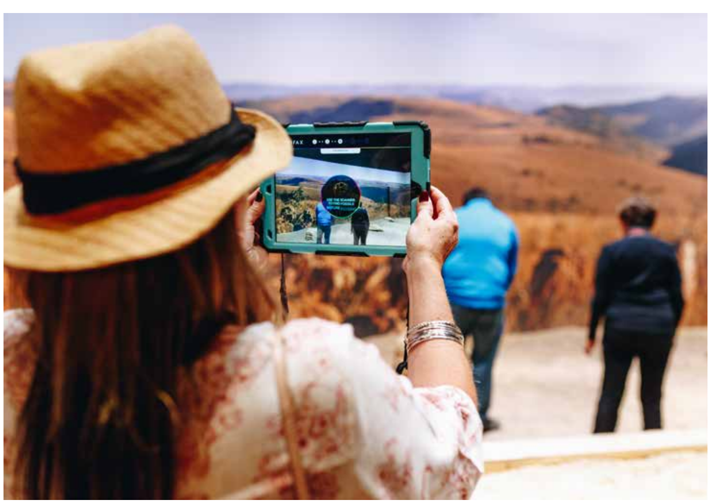
EXHIBITION OVERVIEW

The *Center for the Exploration of the Human Journey* (CEHJ) at the Perot Museum of Nature and Science is excited to present a once-in-a lifetime educational experience with the temporary exhibition, *Origins: Fossils from the Cradle of Humankind*. This exhibition illuminates the story of human evolution by displaying two unique species of human ancestors discovered in South Africa. We are devoted to uncovering and sharing the fascinating and complex story that is our human journey, and we want to help you utilize this story in your efforts to educate and inspire students. Human evolution can be a fun and engaging way to teach core concepts in biology and life sciences. Much of the exhibition content is written for learners in grades 5 and up, but there are several exhibition features and interactive components designed to engage students of all ages. We hope you and your students enjoy your experience at the museum, and the many lessons and class discussions that this exhibition will inevitably generate. Thank you for helping us further our mission of sharing the science and stories around our shared humanity. We look forward to seeing you.



THE EXHIBITION

Origins: Fossils from the Cradle of Humankind features the original fossils of two species of ancient human relative from South Africa. The 2 million year old remains of *Australopithecus sediba* and the 300,000 year old remains of *Homo naledi* have never before left South Africa for public display, and likely never will again.

Origins celebrates South Africa's rich cultural and natural heritage as well as the diverse research team that contributes to these fossil discoveries. A wide range of scientists and other specialists collaborate to research our human origins and this exhibition highlights many of them. The research team shares a sense of exploration, curiosity, and wonder, and we hope your students can see themselves in one of these roles. We hope your students understand that their skills and interests may one day help with great discoveries in the future and can bring them to interesting and uncharted territory, both physically and intellectually.

HOW TO USE THIS GUIDE

This guide is meant to provide background information and ideas for educators looking to engage with the exhibition to supplement their classroom teaching. You may use the information in the guide to prepare your students for a visit to the *Origins* exhibition, and/or to provide follow-up teaching and lessons that connect back to your curriculum. If you are unable to attend the exhibition with your students, we hope you still choose to use the information and lesson plans provided to engage with the project. You can find helpful resources for educators, including a free virtual reality experience, here: https://www.perotmuseum.org/dinaledivr/index.html.

Although **human** evolution is not addressed directly in the Texas Essential Knowledge and Standards (TEKS), there is tremendous overlap between the standards and the scientific concepts that are fundamental to understanding human evolution. Additionally, the high school TEKS address evolutionary theory in great detail. Educators are encouraged to use this subject matter to discuss adaptation, ecosystems, DNA, fossils, natural selection, scientific process, inquiry, and many other topics. We have provided several lesson plans, and a thorough TEKS-alignment that connects the exhibition with several different content areas, so educators responsible for teaching all subjects can identify areas of potential interest for their students.

BACKGROUND INFORMATION

KEY CONCEPTS

The exhibition is focused around two fossil hominin discoveries made in the Cradle of Humankind, South Africa. The real fossils, not replicas or models, are on display in the exhibit. *Australopithecus sediba* was discovered at a site called 'Malapa' in 2008. *Homo naledi* was discovered about 18 kilometers (11 miles) away in the Rising Star cave system in 2013. Both expeditions were led by renowned paleoanthropologist, and Distinguished Science Advisor for the Perot Museum, Lee Berger.

THE CRADLE OF HUMANKIND

The Cradle of Humankind is an approximately 290 square kilometer (180 square mile) area about 50 kilometers (31 miles) northwest of Johannesburg in the Gauteng province of South Africa. The area was recognized in 1999 as a UNESCO World Heritage Site for its rich history of important paleoanthropological finds. There are more than 35 fossil-bearing caves in the Cradle of Humankind, and these caves have produced some of the most important and well-known specimens in the history of the discipline. The geological conditions in the Cradle of Humankind allow fossils to preserve at a much higher rate than in other areas of Africa. It is important for students to understand that the sheer volume of remains found in this area does not mean that all of humanity began here, as the designation may suggest, but that fossils preserve better here, and the region therefore provides a tremendous opportunity for paleoanthropologists to learn more about our species' origins.

AUSTRALOPITHECUS SEDIBA

Australopithecus sediba was discovered in 2008 by Lee Berger's 9-year old son, Matthew Berger. Matthew was playing near the Malapa site while his father worked, when he came across a large rock with a fossil in it. Dr. Berger observed what his son had found, and the story of *Australopithecus sediba* began. Matthew Berger, at just 9 years old, had found the approximately 2 million-year-old remains of a juvenile hominin. Two years later, in 2010, Lee Berger and colleagues would announce that these remains represented an entirely new species. The research team designated the skeleton Matthew found MH-1 and nicknamed it "Karabo." It is the holotype, meaning that it is the specimen used to describe the species. The original fossils of the MH-1 skeleton (not replicas or models) are on display at the Perot Museum for guests to view.

The site of Malapa is an ancient eroded cave that was mined in the early 20th century. The rocks from the cave contain many fossils of hominins and other animals. Based on the evidence, researchers hypothesize the cave opening was a natural "death trap" into which animals fell over time. Earth science educators can use the Malapa site to discuss cave formation and other key geological concepts.

HOMO NALEDI

Homo naledi was discovered by recreational cavers in 2013. The cavers, Rick Hunter and Steven Tucker, took photos of the bones that they found in the Dinaledi Chamber of the Rising Star cave system and showed them to Lee Berger. Dr. Berger received funding from the National Geographic Society and the University of the Witwatersrand in Johannesburg to mount an expedition and uncover more fossil material from the chamber. Six researchers were appointed to enter the difficult-to-reach cave chamber and systematically excavate the fossils. These scientists were dubbed the, "Underground Astronauts." Becca Peixotto, director of the CEHJ at the Perot Museum, was a member of this cohort.

The number of fossils uncovered during the initial excavations was very impressive. Additionally, scientists were puzzled at the context of the fossil finds. Over 1,200 fossils were uncovered deep underground, through a maze of narrow, difficult-to-access passages. This is a highly unusual context for paleoanthropological discoveries and researchers hypothesize that the placement of these bones in the Dinaledi Chamber was not the result of natural phenomena, but of hominin behavior. The partial *Homo naledi* skeleton designated LES-1, and nicknamed "Neo," is on display in the exhibit for guests to view.

THE DELIBERATE DISPOSAL HYPOTHESIS

The researchers on the Rising Star team hypothesize that *Homo naledi* deliberately placed deceased members of their species in the deep chambers of the Rising Star cave system. This behavior was purposeful and repeated. This is an incredible realization, because deliberate disposal of the dead is virtually a cultural universal among humans, but *Homo naledi* were not humans. This interpretation has made us question traditional ideas about what it means to be human. Have your students ponder this question, and complete the first writing prompt before and after they have seen the exhibition. Did their ideas change? Why or why not?

ESSENTIAL QUESTIONS

WRITING PROMPTS FOR STUDENTS

1. What makes us human?

2. Why is it important to study human evolution?

3. Why is it important to know where we come from?

4. Some scientists use the ‘biological species concept’ to group living things. How does that differ from the ‘morphological species concept’ many paleoanthropologists use to group fossils?

CONNECTIONS THROUGHOUT THE MUSEUM

To complement the *Origins* exhibition, the Perot Museum is curating several other objects that are either from, or related to South African cultural and natural heritage. These items can be found throughout the Museum in exhibit halls that are most appropriate for their subject matter. Come check out the items below with your students to expand the academic breadth of your field trip and inspire your learners to be curious about different world cultures.

1. **Mother and Baby Sculpture**
   This statue was gifted to former President George W. Bush by the former South African President, Nelson Mandela. Mandela is a revered figure in South Africa and throughout the world for his tremendous work in dismantling apartheid in South Africa and fighting institutional racism and inequality. He served as the first black president of South Africa from 1994 to 1999. Also on display is a copy of a page of the speech Mandela gave at the Rivonia Trial at which he was sentenced to life imprisonment in 1964.

2 ***Thrinaxodon liorhinus* Skeleton**
   This animal is a cynodont that lived about 250 million years ago in South Africa. It was about the size of a fox and probably a burrower, which is one of the reasons that so many have been preserved in the Karoo region of South Africa. Check out the *Thrinaxodon* fossils on the fourth level of the Museum.

3. **San Rock Art**
   The painting on this boulder was created by the San people between 3,000 and 1,500 years ago. The San are an indigenous group in southern Africa that has been living in the area for thousands of years. The artwork depicts two different types of antelope that can be found in the region – an eland and a roebuk. Rock art is an interesting tool to teach students both social studies and artistic concepts.

4. **Fashion Items**
   These clothing items were made by the South African fashion designer, Thabo Makhetha. Her style is a unique combination of traditional motifs and modern South African fashion. Have a look at these beautiful garments on the second level of the Museum in the *Being Human Hall*.

TEKS

ELAR, 5th, 5.6(E)
Make connections to personal experiences, ideas in other texts, and society

ELAR, 5th, 5.6(F)
Make inferences and use evidence to support understanding

ELAR, 5th, 5.13(A)
Generate questions on a topic for formal and informal inquiry

ELAR, 5th, 5.13(C)
Identify and gather relevant information from a variety of sources

ELAR, 6th–8th, 6.8(E)i, 7.8(E)i, 8.8(E)i
Analyze characteristics and structures of argumentative text by identifying the claim

ELAR, 6th, 6.8(E)ii
Analyze characteristics and structures of argumentative text by explaining how the author uses various types of evidence to support the argument

ELAR, 6th–8th, 6.12(A), 7.12(A), 8.12(A)
Generate student-selected and teacher-guided questions for formal and informal inquiry

ELAR, 6th–8th, 6.12(F), 7.12(F), 8.12(F)
Synthesize information from a variety of sources

ELAR, 7th, 7.8(E)ii
Analyze characteristics and structures of argumentative text by explaining how the author uses various types of evidence and consideration of alternatives to support the argument

ELAR, ENG1, ENG2, E1.7(E)I, E1.7(E)i
Analyze characteristics and structural elements of argumentative texts such as clear arguable claim, appeals, and convincing conclusion

ELAR, ENG1, ENG2, E1.7(E)ii, E2.7(E)ii
Analyze characteristics and structural elements of argumentative texts such as various types of evidence and treatment of counterarguments, including concessions and rebuttals

ELAR, ENG1, ENG2, E1.11(A), E2.11(A)
Develop questions for formal and informal inquiry

ELAR, ENG1, ENG2, E1.11(F), E2.11(F)
Synthesize information from a variety of sources

Math, 6th, 6.4(B)
Apply qualitative and quantitative reasoning to solve prediction and comparison of real-world problems involving ratios and rates

Math, 7th, 7.5(A)
Generalize the critical attributes of similarity, including ratios within and between similar shapes

Math, 7th, 7.5(C)
Solve mathematical and real-world problems involving similar shape and scale drawings

Math, 7th, 7.6(F)
Use data from a random sample to make inferences about a population

Math, 7th, 7.12(C)
Compare two populations based on data in random samples from these populations, including informal comparative inferences about differences between the two populations

Math, 8th, 8.3(A)
Generalize that the ratio of corresponding sides of similar shapes are proportional, including a shape and its dilation

Math, ALG1, A1.4(B)
Compare and contrast association and causation in real-world problems

Math, ALG2, A2.8(C)
Predict and make decisions and critical judgments from a given set of data using linear, quadratic, and exponential models

Math, GEO, G.13(D)
Apply conditional probability in contextual problems

Math, PRECALC, PC.2(N)
Analyze situations modeled by functions, including exponential, logarithmic, rational, polynomial, and power functions, to solve real-world problems

Science, 5th, 5.9(D)
Identify fossils as evidence of past living organisms and the nature of the environments at the time using models

Science, 5th, 5.10(A)
Compare the structures and functions of different species that help them live and survive in a specific environment such as hooves on prairie animals or webbed feet in aquatic animals

Science, 7th, 7.12(A)
Investigate and explain how internal structures of organisms have adaptations that allow specific functions such as gills in fish, hollow bones in birds, or xylem in plants

Science, BIO, B.7(A)
Analyze and evaluate how evidence of common ancestry among groups is provided by the fossil record, biogeography, and homologies, including anatomical, molecular, and developmental

Science, BIO, B.2(C)
Know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well established and highly reliable explanations, but they may be subject to change as new areas of science and new technologies are developed

Science, BIO, B.2(D)
Distinguish between scientific hypotheses and scientific theories

Science, ESS, ESS.8(A)
Analyze and evaluate a variety of fossil types such as transitional fossils, proposed transitional fossils, fossil lineages, and significant fossil deposits with regard to their appearance, completeness, and alignment with scientific explanations in light of the fossil data

History, 6th, 6.18(A)
Identify examples of scientific discoveries, technological innovations, and scientists and inventors that have shaped the world

History, 6th, 6.19(A)
Differentiate between, locate, and use valid primary and secondary sources such as oral, print, and visual material and artifacts to acquire information about various world cultures

History, World History, WH.15(A)
Locate places and regions of historical significance directly related to major eras and turning points in world history

History, World History, WH.15(B)
Analyze the influence of human and physical geographic factors on major events in world history such as the development of river valley civilizations, trade in the Indian Ocean, and the opening of the Panama and Suez canals

History, World History, WH.28(A)
Identify methods used by archaeologists, anthropologists, historians, and geographers to analyze evidence

History, World History, WH.28(B)
Explain how historians analyze sources for frame of reference, historical context, and point of view to interpret historical events

History, World History, WH.28(C)
Analyze primary and secondary sources to determine frame of reference, historical context, and point of view

History, World Geography, WG.21(D)
Analyze information by sequencing, categorizing, identifying cause-and-effect relationships, comparing, contrasting, finding the main idea, summarizing, making generalizations and predictions, drawing inferences and conclusions, and developing connections over time

CTE, Ag/Food/Nat Resources, 130.2(4C)
Evaluate significant historical and current agriculture, food, and natural resources developments;

CTE, Printing/Imaging, 130.94(11M)
Identify graphic design concepts such as contrast, alignment, repetition, and proximity

CTE, Principles of Government, 130.202(9E)
Explore how geographic information systems assist in gathering information;

CTE, Principles of Government, 130.202(12E)
Analyze the potential impact on society of recent scientific discoveries and technological innovations

CTE, Principles of Applied Engineering, 130.402(5D)
Predict possible changes caused by the advances of technology

CTE, Principles of Applied Engineering, 130.402(6A)
Identify and describe the fundamental processes needed for a project, including the design process and prototype development and initiating, planning, executing, monitoring and controlling, and closing a project

STEM, Scientific Research and Design, 130.417(6A)
Identify the scientific methodology used by a researcher

STEM, Scientific Research and Design, 130.417(6B)
Examine a prescribed research design and identify dependent and independent variables;

STEM, Scientific Research and Design, 130.417(6C)
Evaluate a prescribed research design to determine the purpose for each of the procedures performed

STEM, Scientific Research and Design, 130.417(6D)
Compare the relationship of the hypothesis to the conclusion

STEM, Scientific Research and Design, 130.417(9A)
Synthesize and justify conclusions supported by research data

STEM, Scientific Research and Design, 130.417(9B)
Consider and communicate alternative explanations for observations and results

STEM, Scientific Research and Design, 130.417(9C)
Identify limitations within the research process and provide recommendations for additional research

CTE, Forensic Science, 130.339(16A)
Identify the major bones of the human skeletal system

CTE, Forensic Science, 130.339(16D)
Explain the characteristics of the human skeletal system indicative of specific gender, racial origin, and approximate range of age and height

CTE, Forensic Science, 130.339(16E)
Explain the role of dental records in identification of human remains

Art, 5th, 117.117(3B)
Compare the purpose and effectiveness of artworks created by historic and contemporary men and women, making connections to various cultures

Art, 5th, 117.117(3C)
Connect art to career opportunities for positions such as architects, animators, cartoonists, engineers, fashion designers, film makers, graphic artists, illustrators, interior designers, photographers, and web designers

Art, 5th, 117.117(3D)
Investigate connections of visual art concepts to other disciplines

Art, Middle School 1, 117.202(3B)
Identify examples of art that convey universal themes such as beliefs, cultural narrative, life cycles, the passage of time, identity, conflict, and cooperation

Art, Middle School 1, 117.202(3D)
Explore career and avocational opportunities in art such as various design, museum, and fine arts fields

Art, Middle School 1, 117.202(4D)
Investigate and explore original artworks in a variety of venues outside of the classroom such as museums, galleries, or community art

Art, Middle School 1, 117.202(4E)
Understand and demonstrate proper exhibition etiquette

Art, Middle School 2, 117.203(3B)
Analyze selected artworks to determine contemporary relevance in relationship to universal themes such as belief, cultural narrative, life cycles, the passage of time, identity, conflict, and cooperation;

Art, Middle School 2, 117.203(3D)
Identify career and avocational choices in art such as various design, museum, and fine arts fields.

Art, Middle School 2, 117.203(4D)
Investigate and explore original artworks in a variety of venues outside of the classroom such as museums, galleries, or community art; and

Art, Middle School 2, 117.203(4E)
Demonstrate an understanding of and apply proper exhibition etiquette.

Art, Middle School 3, 117.204(3B)
Analyze cultural ideas expressed in artworks relating to social, political, and environmental themes such as environment/nature, conflict and power, relationships to others, and reality/fantasy;

Art, Middle School 3, 117.204(3D)
Compare and contrast career and avocational opportunities in art such as various design, museum, and fine arts fields.

Art, Middle School 3, 117.204(4C)
Investigate and explore original artworks in a variety of venues outside of the classroom such as museums, galleries, or community art; and

Art, Middle School 3, 117.204(4D)
Understand and demonstrate proper exhibition etiquette.

Art, High School Art 1, 117.302(4A)
Interpret, evaluate, and justify artistic decisions in artwork by self, peers, and other artists such as that in museums, local galleries, art exhibits, and websites

Art, High School Art 1, 117.302(4D)
Select and analyze original artwork, portfolios, and exhibitions to form precise conclusions about formal qualities, historical and cultural contexts, intentions, and meanings

Art, High School Art 2, 117.303(4A)
Interpret, evaluate, and justify artistic decisions in artwork by self, peers, and other artists such as that in museums, local galleries, art exhibits, and websites

Art, High School Art 2, 117.303(4E)
Select and analyze original artwork, portfolios, and exhibitions to form precise conclusions about formal qualities, historical and cultural contexts, intentions, and meanings

Art, High School Art 3, 117.304(4A)
Interpret, evaluate, and justify artistic decisions in artwork such as that in museums, local galleries, art exhibits, and websites based on evaluation of developmental progress, competency in problem solving, and a variety of visual ideas

Art, High School Art 3, 117.304(4F)
Select and analyze original artwork, portfolios, and exhibitions to demonstrate innovation and provide examples of in-depth exploration of qualities such as aesthetics; formal, historical, and cultural contexts; intentions; and meanings

Art, High School Art 4, 117.305(4A)
Develop evaluative criteria to justify artistic decisions in artwork such as that in museums, local galleries, art exhibits, and websites based on a high level of creativity and expertise in one or more art areas

Art, High School Art 4, 117.305(4F)
Evaluate a wide range of artwork to form conclusions about formal qualities, aesthetics, historical and cultural contexts, intents, and meanings

Science, AP Biology, EU EVO-1
Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.

Science, AP Biology, EVO 1.M.1
Evolution is supported by scientific evidence from many disciplines (geographical, geological, physical, biochemical, and mathematical data).

Science, AP Biology, EVO 1.N.1
Molecular, morphological, and genetic evidence from extant and extinct organisms adds to our understanding of evolution— a. Fossils can be dated by a variety of methods. These include: i. The age of the rocks where a fossil is found ii. The rate of decay of isotopes including carbon-14 iii. Geographical data b. Morphological homologies, including vestigial structures, represent features shared by common ancestry

Science, AP Biology, EU EVO-2
Organisms are linked by lines of descent from common ancestry.

Science, AP Biology, EVO 2.B.2
Structural and functional evidence supports the relatedness of organisms in all domains.

Science, AP Biology, EU EVO-3
Life continues to evolve within a changing environment.

Science, AP Biology, EVO 3.B.1
Phylogenetic trees and cladograms show evolutionary relationships among lineages— a. Phylogenetic trees and cladograms both show relationships between lineages, but phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock. b. Traits that are either gained or lost during evolution can be used to construct phylogenetic trees and cladograms— i. Shared characters are present in more than one lineage. ii. Shared, derived characters indicate common ancestry and are informative for the construction of phylogenetic trees and cladograms. iii. The out-group represents the lineage that is least closely related to the remainder of the organisms in the phylogenetic tree or cladogram. c. Molecular data typically provide more accurate and reliable evidence than morphological traits in the construction of phylogenetic trees or cladograms.

Science, AP Biology, EVO 3.C.1
Phylogenetic trees and cladograms can be used to illustrate speciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages

Science, AP Biology, EVO 3.C.2
Phylogenetic trees and cladograms can be constructed from morphological similarities of living or fossil species and from DNA and protein sequence similarities.

Science, AP Biology, EVO 3.C.3
Phylogenetic trees and cladograms represent hypotheses and are constantly being revised, based on evidence.

ACTIVITIES

We have compiled several activities that can be used to supplement your Museum visit. The first three lesson plans are geared towards learners in middle school and high school, and they deal directly with paleoanthropology and hominids. The final two lesson plans are written for younger students in elementary school. They focus on the paleoanthropological/archaeological research process and fundamental scientific skills such as measurement, data analysis, and research design. Additionally, we have provided a writing or discussion prompt before the activities that can be used to engage your students in this research and encourage them to examine and interpret archaeological evidence.

We hope that these lesson plans provide both inspiration and concrete examples of how anthropology can be an engaging tool for teaching cross-curricular concepts. Thank you for using this guide, and please feel free to get in touch with the CEHJ on Twitter, @PerotMuseumCEHJ.

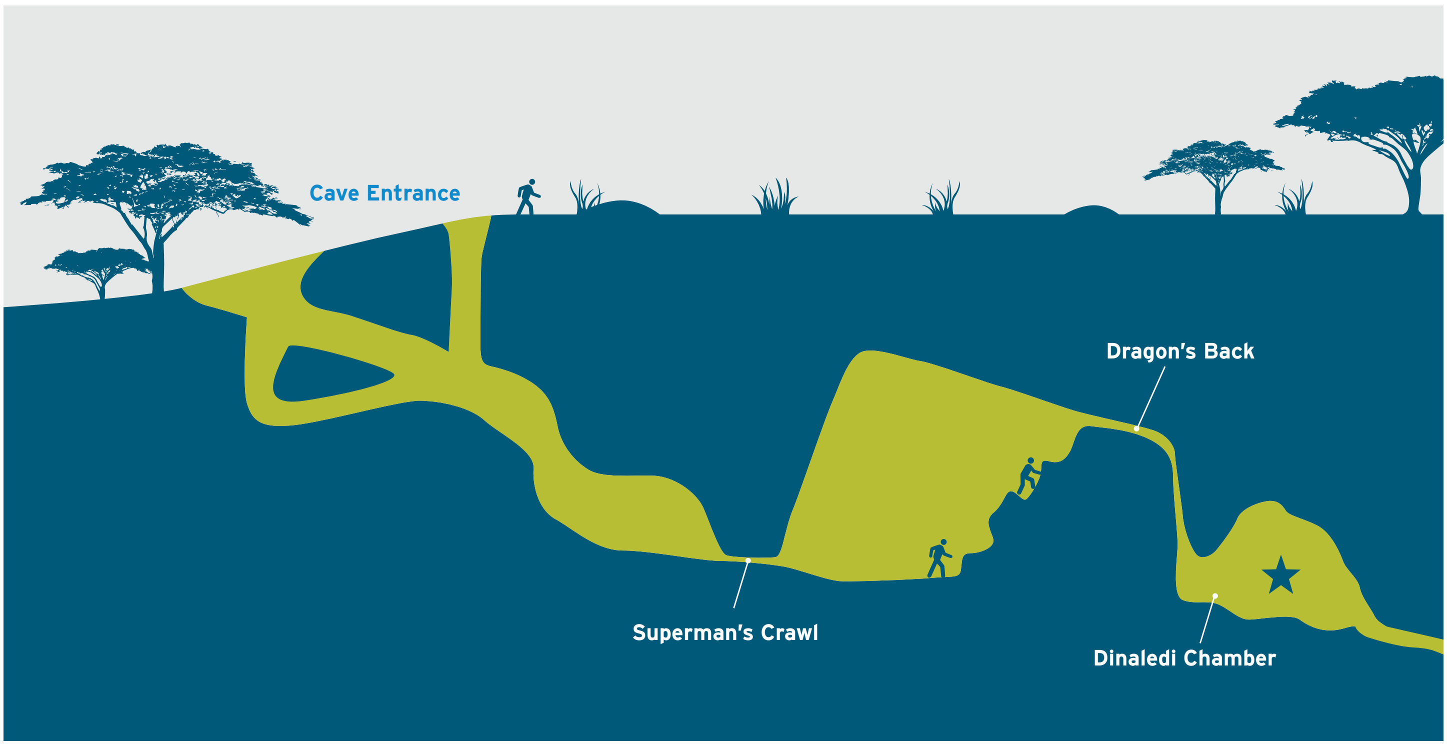
ACTIVITY 1 – CLASS DISCUSSION

GUIDING QUESTIONS

1. How do you think the fossils of *Homo naledi* ended up in the Dinaledi chamber?
2. Do you agree that they were placed there deliberately?
3. Can you think of another explanation that is supported by the evidence? Consider the circumstances outlined below:

WHERE DID THE RESEARCHERS FIND THE FOSSILS?

Scientists are excavating the fossils in a cave chamber deep in the ground. There are several difficult-to-traverse passages that only very experienced rock climbers can access. Here is a diagram of where the bones were found:



The tiny area between the "Dragon's Back" and the Dinaledi Chamber is called the "Chute." In its most narrow place, the Chute is only about 7-8 inches wide. That means that the scientists have to squeeze themselves through a rocky passage that is only about the size of a dollar bill. The Chute is about 40 feet long. This is an incredibly difficult obstacle. The scientists access it with modern gear and safety protocols. How did the bones of *Homo naledi* find their way down there 250,000 years ago?

COULD CARNIVORES HAVE BROUGHT THE BONES INTO THE CHAMBER?
Scientists found no evidence of carnivore activity on the fossils of *Homo naledi*. Usually researchers can tell if scavengers have interfered with the bones by finding teeth marks, but they don't see that with *Homo naledi*. Also, go back to the diagram of the cave chamber. What else about the cave makes this scenario unlikely? (Have students consider the difficulty of getting in and out of the cave for carnivores.)

COULD A NATURAL EVENT, LIKE A FLOOD, HAVE PUSHED THE BONES INTO THE CHAMBER?
Scientists find no evidence of water movement in the cave. In fact, all of the soil on the floor of the Dinaledi Chamber appears to have come from inside the chamber, so geologists believe that the "Dragon's Back" formation effectively blocked any water from ever entering the chamber.

Can your students think of any other explanations? Watch this video for reference in discussing this hypothesis: https://www.youtube.com/watch?v=qxcrg1jHKWA.

ACTIVITY 2 – SPLITTING AND LUMPING

INTRODUCTION

Today we will be exploring the concept of 'lumpers vs. splitters' through the analysis of four hominin crania. You will play the part of the paleoanthropologist and will help determine whether all four specimens should be grouped together as one genus or separately as two different genera.

LEARNING OBJECTIVES

- Understand what it means to be a species (as well as the difference between genus and species)
- Contrast the difference between inter and intragroup variation.
- Understand and interpret phylogenies
- Describe the morphological differences distinguishing robust and gracile australopithecines
- Understand the debate between splitting and lumping and be able to articulate your views on the subject matter

INTRODUCTORY QUESTIONS

1. What is a phylogeny?

2. Why do paleoanthropologists use phylogenies?

3. What types of characteristics do paleoanthropologists look at when they are grouping different hominin fossils? (Hint: Think about what they look like).

4. Why might two paleoanthropologists come up with two different phylogenies despite looking at the same fossils?

PART 1: VISUAL ASSESSMENT

Begin by visually assessing all four of the crania provided for you at the beginning of the lab for the provided traits. Write down your observations for each. Do not worry about the preservation of the fossil (i.e. missing pieces)—this varies based on the specimen and doesn't help you learn about the relationship between the various organisms. If you cannot observe a trait, write N/A. Refer to the osteology guide if you need help understanding what the various traits are.

TRAIT	A	B	C	D
Is the face flat/dished or more rounded like modern humans?				
Are the cheekbones big and flat or small and rounded?				
Is the brow ridge prominent or reduced?				
Is there post-orbital constriction present?				
How large are the teeth?				
Is the skull more prognathic or orthognathic?				
Is there a sagittal crest?				
Is the cranium gracile or robust?				

1. Do any of the specimens share multiple traits in common? Which ones?

2. Paleoanthropologists often ascertain the 'relatedness' of different species based on how many traits they share in common. If that is the case, which of the specimens do you think are more likely to be more closely related to one another?

PART 2: SPLITTERS AND LUMPERS

When determining how to group a set of organisms, there are multiple ways in which scientists can go about it. Some scientists make many groups, while some make only a few. Based on how they group organisms, scientists can be considered either 'splitters' or 'lumpers'.

Lumpers tend to group similar organisms into a single species. Splitters, on the other hand, tend to divide organisms into multiple different subspecies. The problem of how to best group different organisms is one that is commonly faced by paleoanthropologists.

1. Based on the criteria above, how would you group the specimens above? (Are they all different enough to warrant separate groups? Should they all be grouped together? Are there some groups that can be made within the set of four specimens?). Explain your justification.

2. Based on your answer to the previous question, would you be considered a lumper or a splitter? Why?

3. Many paleoanthropologists would group specimens A and B together and specimens C and D together. Which traits do you think that they would use to make this grouping?

PART 3: COMPARATIVE MORPHOLOGY AND ADAPTATION

Paleoanthropologists often ask themselves, "Why do these specimens look different from one another?" Part of their job is to figure out if the specimens look different because of normal intraspecies variation (the same reason that everyone in your class has their own unique characteristics) or if some of these differences are the result of adaptation. If the traits are the result of adaptation, they then must figure out how that adaptation allowed the species to thrive in its environment.

One example of adaption is the presence of a sagittal crest. The sagittal crest is where our chewing muscles attach on the top of our head. The bigger the sagittal crest, the larger the chewing muscles that can attach there.

1. Based on the chart above, which of the four specimens have a prominent sagittal crest?

2. Based on the information above, which of the specimens would have had more powerful chewing?

3. Now look at the teeth of all of the specimens. Are they similar or different? (You can consult the chart above)

4. Does the answer to question 3 make sense in relation to the answer to question 2? Why or why not?

5. Two of the specimens given to you predominantly eat grasses, leaves, and fruits, while the other two predominately practiced hard/tough object feeding (grasses, sedges, tubers, etc.). Based on the morphology of the crania you analyzed, which specimens do you think had which diet?

FINAL QUESTIONS

1. Based on everything you have learned today, how would you group the four specimens? Did your answer change or stay the same from Part 2?

2. The postcranial skeletons (everything other than the skull) of these specimens are nearly indistinguishable. Does this impact your answer to the previous question? Why or why not?

3. What are some of the challenges that paleoanthropologists might face in making these decisions? (Hint: think about the process of finding the fossils—do we find a lot of them? Are they typically broken or whole? Is there room for interpretation in visual morphological analysis?)

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If you need help locating these 3D print files, please reach out to Molly Selba at https://www.hetmp.com.

ACTIVITY 2 – SPLITTING AND LUMPING (TEACHER'S GUIDE)

INTRODUCTION

Today the class will be exploring the concept of 'lumpers vs. splitters' through the analysis of four hominin crania. Students will play the part of the paleoanthropologist and will help determine whether all four specimens should be grouped together as one genus or separately as two different genera.

BEFORE GETTING STARTED

- Have students review the first three topics covered in the teaching materials associated with Module 2.
- Make sure students have access to 3D prints/3D pdfs of *Paranthropus aethiopicus*, *Paranthropus boisei*, *Australopithecus africanus*, and *Australopithecus sediba*. If these prints/PDFs are labeled, please blind them using the following labels:

  Paranthropus aethiopicus = A
  Paranthropus boisei = B
  Australopithecus africanus = C
  Australopithecus sediba = D
- Print out the lab worksheets associated with this activity and make sure that one is available to every student.

ANSWERS TO INTRODUCTORY QUESTIONS

1. What is a phylogeny?
   A diagram that depicts the lines of evolutionary descent of different species, organisms, or genes from a common ancestor or a way that paleontologists show the connections between different organisms and how they relate to one another.
2. Why do paleoanthropologists use phylogenies?
   In order to better understand how we as humans evolved over time, it is important to understand our relationships with other hominins. Phylogenies help demonstrate this relationship.
3. What types of characteristics do paleoanthropologists look at when they are grouping different hominin fossils? (Hint: Think about what they look like).
   Paleoanthropologists tend to focus on morphological differences (i.e. differences in shape) when they are grouping different fossils. Aspects like the shape and size of the skull, how large the teeth are, etc. can all help paleoanthropologists group the fossils into their various designations.
4. Why might two paleoanthropologists come up with two different phylogenies despite looking at the same fossils?
   Two paleoanthropologists may come up with different phylogenies by looking at the same fossils because a lot of the interpretation of these fossils in subjective. The two paleoanthropologists may consider the value of a trait differently or could have different opinions of inter- vs. intragroup variation.

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ANSWERS TO PART 1: VISUAL ASSESSMENT

TRAIT	A	B	C*	D
Is the face flat/dished or more rounded like modern humans?	*Flat/dished face*	*Flat/dished face*	*More rounded like modern human*	*More rounded like modern human*
Are the cheekbones big and flat or small and rounded?	*Big and flat*	*Big and flat*	*Small and rounded*	*Small and rounded*
Is the brow ridge prominent or reduced?	*Prominent brow ridge*	*Prominent brow ridge*	*Reduced brow ridge*	*Reduced brow ridge*
Is there post-orbital constriction present?	*Yes (it is pinched behind the orbits)*	*Yes (it is pinched behind the orbits)*	*Slightly*	*Slightly*
How large are the teeth?	*N/A*	*Very large*	*Small*	*Medium*
Is the skull more prognathic or orthognathic?	*Prognathic (protruding midface)*	*Prognathic (protruding midface)*	*Orthognathic*	*Orthognathic*
Is there a sagittal crest?	*Sagittal crest present (flange at top of skull)*	*Sagittal crest present (flange at top of skull)*	*No*	*No*
Is the cranium gracile or robust?	*Robust*	*Robust*	*Gracile*	*Gracile*

*If you are using loner set 1 or 2 you will be looking at a more incomplete *Paranthropus boisei*. The .stl file/3D PDF of *Paranthropus boisei* currently on the HETMP website feature a more complete specimen. This lab can be done with the more incomplete specimen, however, it may be beneficial to supplement the fragmentary *Paranthropus boisei* cranium with the newer 3D PDF.

1. Do any of the specimens share multiple traits in common? Which ones?
   Specimens A and B share many traits in common. Specimens C and D also share many traits in common.

2. Paleoanthropologists often ascertain the 'relatedness' of different species based on how many traits they share in common. If that is the case, which of the specimens do you think are more likely to be more closely related to one another?
   A and B will be more related to each other than they are to C and D. C and D will be more related to each other than they are to A and B.

ANSWERS TO PART 2: SPLITTERS AND LUMPERS

1. Based on the criteria above, how would you group the specimens above? (Are they all different enough to warrant separate groups? Should they all be grouped together? Are there some groups that can be made within the set of four specimens?). Explain your justification.
   Correct answers include grouping all found specimens together in one group or grouping A and B together in one group while grouping C and D in another group.
2. Based on your answer to the previous question, would you be considered a lumper or a splitter? Why?
   If they have one group then they would be considered a lumper. If they have two groups then they would be considered a splitter.
3. Many paleoanthropologists would group specimens A and B together and specimens C and D together. Which traits do you think that they would use to make this grouping?
   Any of the traits in the above chart would work for this answer.

ANSWERS TO PART 3: COMPARATIVE MORPHOLOGY AND ADAPTATION

1. Based on the chart above, which of the four specimens have a prominent sagittal crest?
   Specimens A and B have a sagittal crest.
2. Based on the information above, which of the specimens would have had more powerful chewing?
   Specimens A and B because they would have been able to have larger chewing muscles.
3. Now look at the teeth of all of the specimens. Are they similar or different? (You can consult the chart above)
   Specimens A and B have larger teeth.
4. Does the answer to question 3 make sense in relation to the answer to question 2? Why or why not?
   It would make sense that larger chewing muscle attachment sites would be paired with larger teeth.
5. Two of the specimens given to you predominantly eat grasses, leaves, and fruits, while the other two predominately practiced hard/tough object feeding (grasses, sedges, tubers, etc.). Based on the morphology of the crania you analyzed, which specimens do you think had which diet?
   Specimens A and B were hard object feeders while specimens C and D were not.

FINAL QUESTIONS

1. Based on everything you have learned today, how would you group the four specimens? Did your answer change or stay the same from Part 2?
   Answers will vary. Be sure that students can appropriately justify their taxonomy.
2. The postcranial skeletons (everything other than the skull) of these specimens are nearly indistinguishable. Does this impact your answer to the previous question? Why or why not?
   Again, answers will vary. Students should be able to get a sense from this question that paleoanthropology is not an exact science and that there is a fair amount of interpretation. Is the cranial morphology more important than that of the postcrania? Are these specimens still different enough to warrant their own genera?
3. What are some of the challenges that paleoanthropologists might face in making these decisions?
   Few number of fossils, they are usually fragmented, room for interpretation, etc.

TEKS

7.11 (B) Explain variation within a population or species by comparing external features, behaviors, or physiology of organisms that enhance their survival such as migration, hibernation, or storage of food in a bulb

High School Biology
7 (A) Analyze and evaluate how evidence of common ancestry among groups is provided by the fossil record, biogeography, and homologies, including anatomical, molecular, and developmental
7 (E) Analyze and evaluate the relationship of natural selection to adaptation and to the development of diversity in and among species

ACTIVITY 3 – A COMPARISON OF HOMININS USING FOSSILS SUCH AS TEETH AND SKULLS

INTRODUCTION

The role of a paleoanthropologist is to reconstruct the lives of various extinct species through the analysis of the bones that they left behind. Specifically, by measuring the teeth of extinct species, paleoanthropologists can reconstruct their diet. This method is used on fossils of all different kinds, and is even used to learn more about our closest human relatives.

In this lab exercise, you will play the part of the paleoanthropologist and have to determine the diet of two species of hominins. The term 'hominin' refers to humans and all of their direct ancestors. One of the mandibles provided for you is from *Homo heidelbergensis*, a hominin that lived approximately 700 thousand years ago in Africa. *H. heidelbergensis* was a species very similar to modern humans in terms of body proportions, dental adaptations, and cognitive ability (Rightmire, 2009). The other mandible provided for you is *Paranthropus boisei*, a species that lived in Africa around 2 million years ago. Their brains were roughly the size of modern chimps and gorillas despite having a fairly small body size (approximately 65 lbs. adult females and 85 lbs. for adult males) (McHenry, 1992). Both of these species had drastically different diets, which are reflected by the shape and size of their teeth.

By analyzing the teeth left behind in the jawbones of these hominins, you will be able to demonstrate that not only do these two species have very different dental morphology (i.e. the shape of their teeth), but also that this tooth shape is directly related to their diet.

MATERIALS

For this lab, you will need two hominin mandibles (one belonging to *H. heidelbergensis* and one belonging to *P. boisei*). You will also need a measuring implement (calipers, a ruler, etc.).

HOMININ MANDIBLE COMPARISON

PART 1: To begin, it is important to note which teeth are present in the mandibles (jawbones) of each of the hominin specimens. All hominins have four different types of teeth (including us!). They are:

Incisors: the flat front teeth. Incisors cut food into smaller pieces just like scissors cut paper.

Canines: teeth that tear food apart. They are next to the incisors.

Premolars: the larger, flatter teeth next to the canines. They help grind up the food that we eat.

Molars: the big, flat teeth with sharp ridges found all the way in the back of the mouth. They are perfect for crushing and grinding up food.

All hominins have four incisors, two canines, four premolars, and six molars. They are arranged in the mouth like this:

Human Mandible

Sometimes, individuals can lose some of these teeth during their lives. It is also possible for the teeth to be lost over time (i.e. before the fossils were found by the paleoanthropologist but after the individual died). Now, look at both of the two mandibles provided for you. Mark in the table below which teeth are present (P) and which are missing (x). The teeth are listed from the left side of the dental arcade to the right:

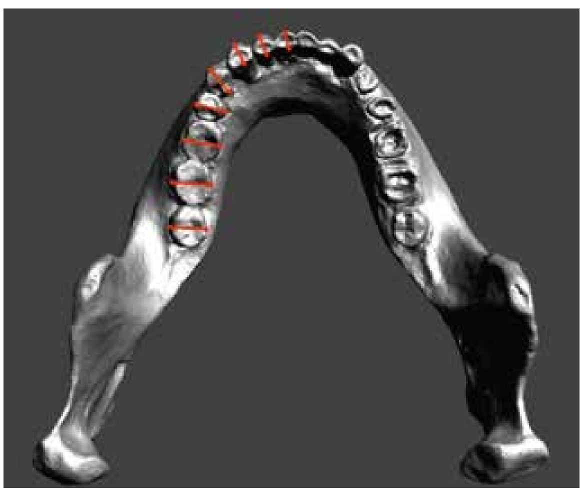
HOMININ	M	M	M	P	P	C	I	I	I	I	C	P	P	M	M	M
H. heidelbergensis																
P. boisei																

Tooth Type Totals for H. heidelbergensis: # of M ______, P ______, C ______, I ______

Tooth Type Totals for P. boisei: # of M ______, P ______, C ______, I ______

Which of the individuals have more of their teeth present? ____

PART 2: Now that you know which teeth are which, it is time for you to measure the different teeth. For each tooth, you will be taking a measurement called the 'buccolingual width' – it is the measurement of a tooth from the side that your cheek touches (i.e. the part that you can see in the mirror when you smile) to the side that you can touch with your tongue. So 'bucco-' refers to the cheek side of the tooth, while 'lingual' refers to the tongue side. The measurements will look like this:



Buccolingual Width Measurements

Obtaining Tooth Measurements from the Casts

Since the teeth are usually symmetrical in the mouth (the same on one side as the other), you only need to measure the eight teeth on the left side of the mandible. Due to this symmetry, you can say that the hominin dental formula is 2.1.2.3 (2 incisors, 1 canine, 2 premolars and 3 molars). This formula represents one of the four quadrants in the mouth (upper left, upper right, lower left, lower right). If you multiply each tooth type by four you can determine that you as a humans have a total of 32 teeth!

Starting in the middle of the dental arcade and working your way towards the back left side, you will get measurements for two incisors, one canine, two premolars, and three molars (see picture above). Remember to take your measurement across the center (i.e. the widest part) of the tooth!

Fill in your measurements in the table below:

HOMININ	I1	I2	C	P1	P2	M1	M2	M3
H. heidelbergensis								
III								

PART 3: In order to account for any mistakes in your measurements, it is important that the data be averaged to ensure that the measurements are as accurate as possible. Add up the measurements of the people around you (i.e. the I1 measurement from Team 1, I1 measurement from Team 2, I1 measurement from Team 3, etc.) and divide by the number of measurements you added together.

Fill in your average measurements in the table below:

HOMININ	I1	I2	C	P1	P2	M1	M2	M3
H. heidelbergensis								
P. boisei								

Which of teeth have similar measurements (i.e. are the incisors in both species approximately the same size)? In which ways to the teeth of these two species look similar?

Which of the teeth have very different measurements? In which ways do the teeth of these two species look different?

In the beginning of this lab you learned the premolars and molars are for crushing and grinding up food. If that is the case, which of these two species would have molars that would be better at grinding up food? (Hint: Would it be better to have big teeth if you had to grind up hard foods or would it be better to have small teeth?)

PART 4: Now it is time to put all of the information you just found out together and determine the diet of *H. heidelbergensis* and *P. boisei*.

One of these species ate lots of plants (fruits and leaves) as well a variety of other foods (many of which we still eat today). They were avid big-game hunters, produced sophisticated stone tools, and had control of fire (Roebroeks and Villa, 2011). All of these skills allowed them to process their foods, thus making them fairly easy to eat.

The other species only had access to extremely tough foods such as grasses, sedges, and tubers. They were not processing their food, and thus it was extremely tough and difficult to eat. They spent a lot time chewing their foods in order to break them down into small pieces.

Based on the measurements of the teeth that you recorded above which diet did *H. heidelbergensis* have? How about *P. boisei?*

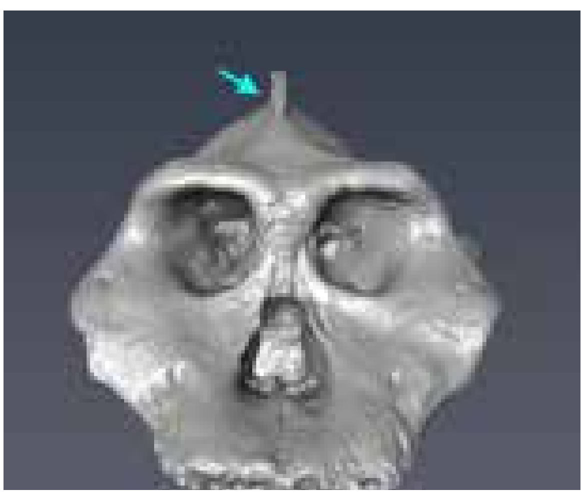
REFLECTIONS

1. Why do you think it is important for paleoanthropologists to understand the diet of our closest hominin relatives?

2. What might be some problems that paleontologists could encounter with doing this type of analysis? (Hint: When fossils are found, are they usually whole or fragmentary?)

3. Modern humans (i.e. Homo sapiens) have teeth that are very similar in shape and size to those of H. heidelbergensis. Based on what you just learned about how the shape and size of teeth reflect diet, would that mean that we eat primarily hard, tough foods or soft, processed foods? Is that true with what the human diet consists of today?

4. Another adaptation to help with chewing hard foods is the presence of larger chewing muscle attachment sites on the cranium. One example of this is the presence of a large flange running down the middle of the skull. This is called the **sagittal crest** and is where the muscles that help you chew hard foods attach to your skull.



Look at the two 3D PDFs provided for you. Which cranium do you think belongs to *H. heidelbergensis*? Which do you think belongs to *P. bosiei*? Why?

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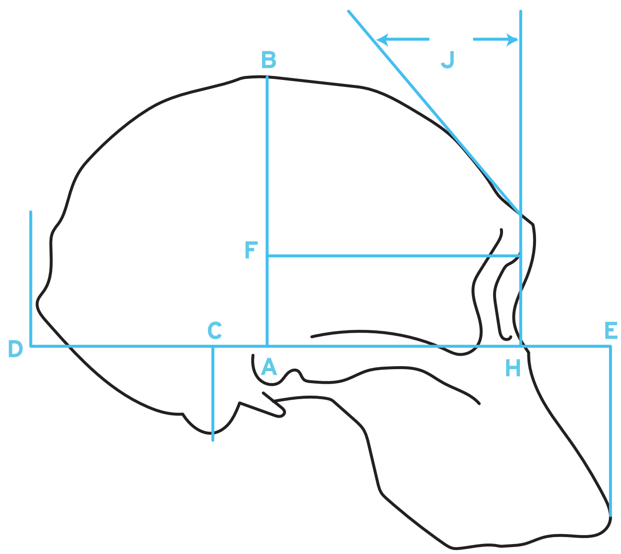
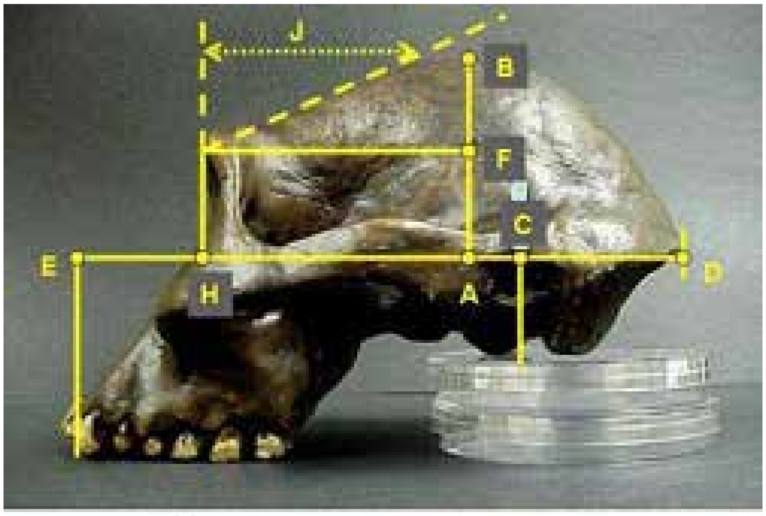
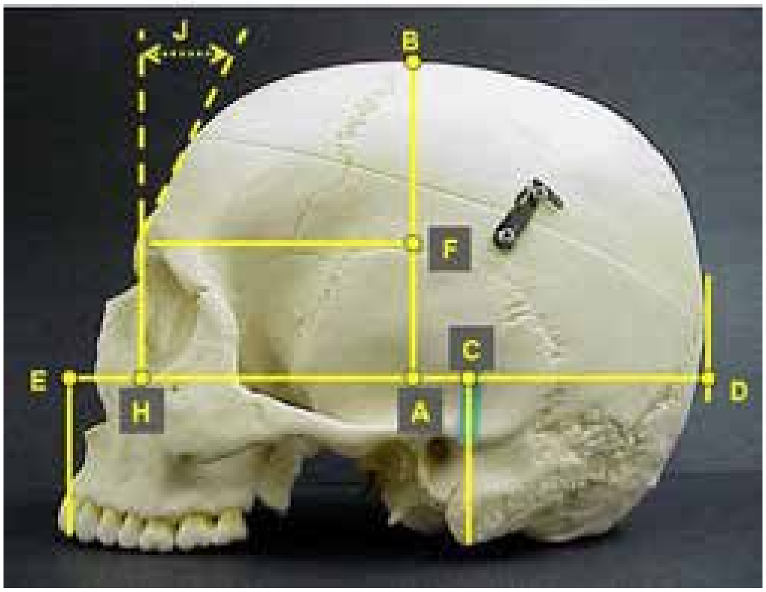
ACTIVITY 4 – HOMINID CRANIOMETRY LAB







BASIC LAYOUT FOR CALCULATING CRANIOMETRIC MEASUREMENTS

Line DE = Draw from the back of the cranium to the farthest forward part of the jaw at the level of the bottom of the eye orbit.

Line AB = Draw from the topmost portion of the cranium to Line DE.

Line C = Draw from the bottommost part of the brain case to Line DE.

Line F = Draw from the top of the eye orbit to Line AB.

Line H = Draw from Line DE to the top of the skull directly in front of the eye orbit.

Line J = Draw following the slope of the forehead connecting with Line H. Passes through the brow ridges if need be.

WHAT DO EACH OF THE MEASUREMENTS MEAN?

Each of these measurements is an INDEX measurement so that you can compare them to each other even if the size of the skulls is different – this allows you to see general trends over time. This also allows you to use this system with other photos of other skulls you may have that were not taken from the same distance.

Foramen Magnum Position (FMP)

- Calculation: (Line CD/Line CE * 100)
- This measurement tells where the foramen magnum is located. A measurement of 100% would mean it is exactly centered between the front of the jaw and the back of the skull. A measurement of 1% would mean it is at the absolute back of the skull.

Brain Height Index (BHI)

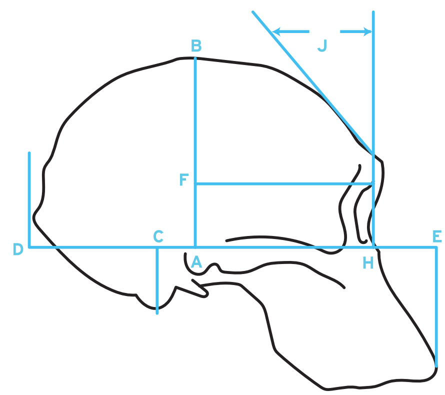
- Calculation: (Line BF/Line AB * 100)
- This comparative measurement indicates how much of the brain is located above the level of the eyes. The higher the index, the more brain is present above the eyes. This index allows you to get a sense of frontal lobe change over time.

Prognathic Index (PI)

- Calculation: (EH/DE * 100)
- This is a measure of how sloped the face is. A creature with a large snout will have a high Prognathic Index, while a flat faced creature would have a smaller number. This index helps demonstrate the change from a more apelike face to a more human like face.

Forehead Slope Angle

- This is measured directly and illustrates the presence of a forehead. The lower the angle, the more modern the forehead is considered. This measurement should **not** take into account any brow ridges which are present.



MEASUREMENTS SKULL #1

Line AB: ______________________mm Line BF: ______________________mm

Line CD: ______________________mm Line CE: ______________________mm

Line DE: ______________________mm Line EH: ______________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

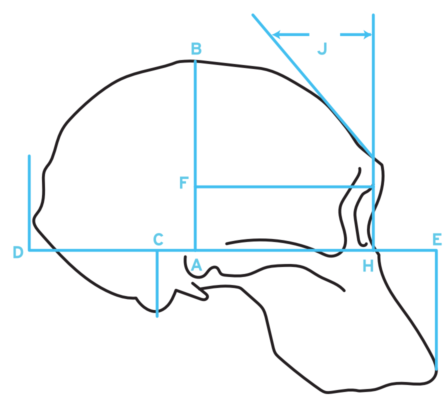
Foramen Magnum Position (CD/CE * 100) = (______________ / _____________)* 100 = _______________

Brain height Index (BF/AB * 100) = (______________ / _____________)* 100 = _______________

Prognathic Index (EH/DE * 100) = (______________ / _____________)* 100 = _______________

Forehead slope angle = ____

MEASUREMENTS SKULL #2



Line AB: ______________________mm Line BF: ______________________mm

Line CD: ______________________mm Line CE: ______________________mm

Line DE: ______________________mm Line EH: ______________________mm

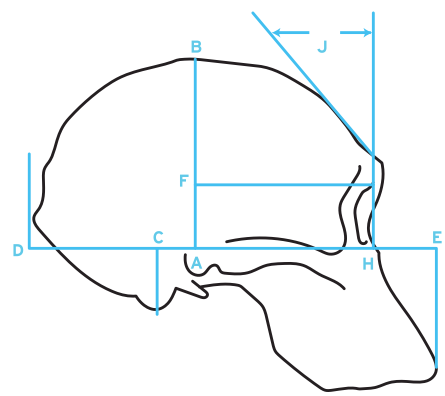
RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

Foramen Magnum Position (CD/CE * 100) = (______________ / _____________)* 100 = _______________

Brain height Index (BF/AB * 100) = (______________ / _____________)* 100 = _______________

Prognathic Index (EH/DE * 100) = (______________ / _____________)* 100 = _______________

Forehead slope angle = _______________________________________



MEASUREMENTS SKULL #3

Line AB: ______________________mm   Line BF: ______________________mm

Line CD: ______________________mm   Line CE: ______________________mm

Line DE: ______________________mm   Line EH: ______________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

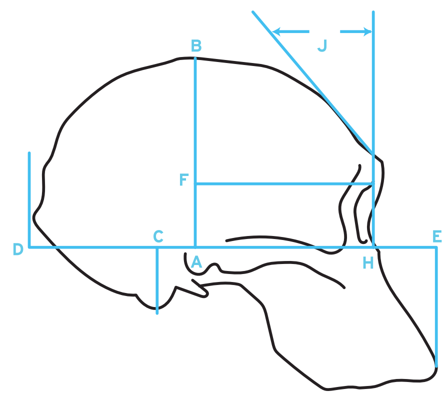
Foramen Magnum Position (CD/CE * 100) = (______________ / _____________)* 100 = _______________

Brain height Index (BF/AB * 100) = (______________ / _____________)* 100 = _______________

Prognathic Index (EH/DE * 100) = (______________ / _____________)* 100 = _______________

Forehead slope angle = _______________________________________

MEASUREMENTS SKULL #4



Line AB: ____________________mm Line BF: ____________________mm

Line CD: ____________________mm Line CE: ____________________mm

Line DE: ____________________mm Line EH: ____________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

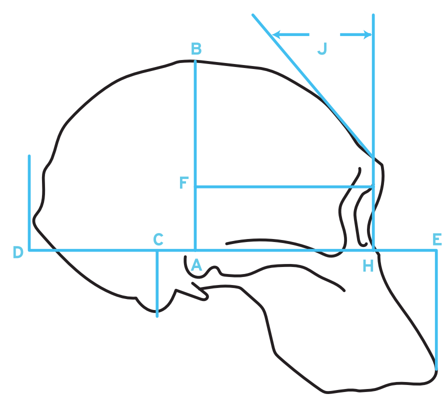
Foramen Magnum Position (CD/CE * 100) = (____________ / ____________)* 100 = ____________

Brain height Index (BF/AB * 100) = (____________ / ____________)* 100 = ____________

Prognathic Index (EH/DE * 100) = (____________ / ____________)* 100 = ____________

Forehead slope angle = ______________________________

MEASUREMENTS SKULL #5



Line AB: ____________________mm Line BF: ____________________mm

Line CD: ____________________mm Line CE: ____________________mm

Line DE: ____________________mm Line EH: ____________________mm

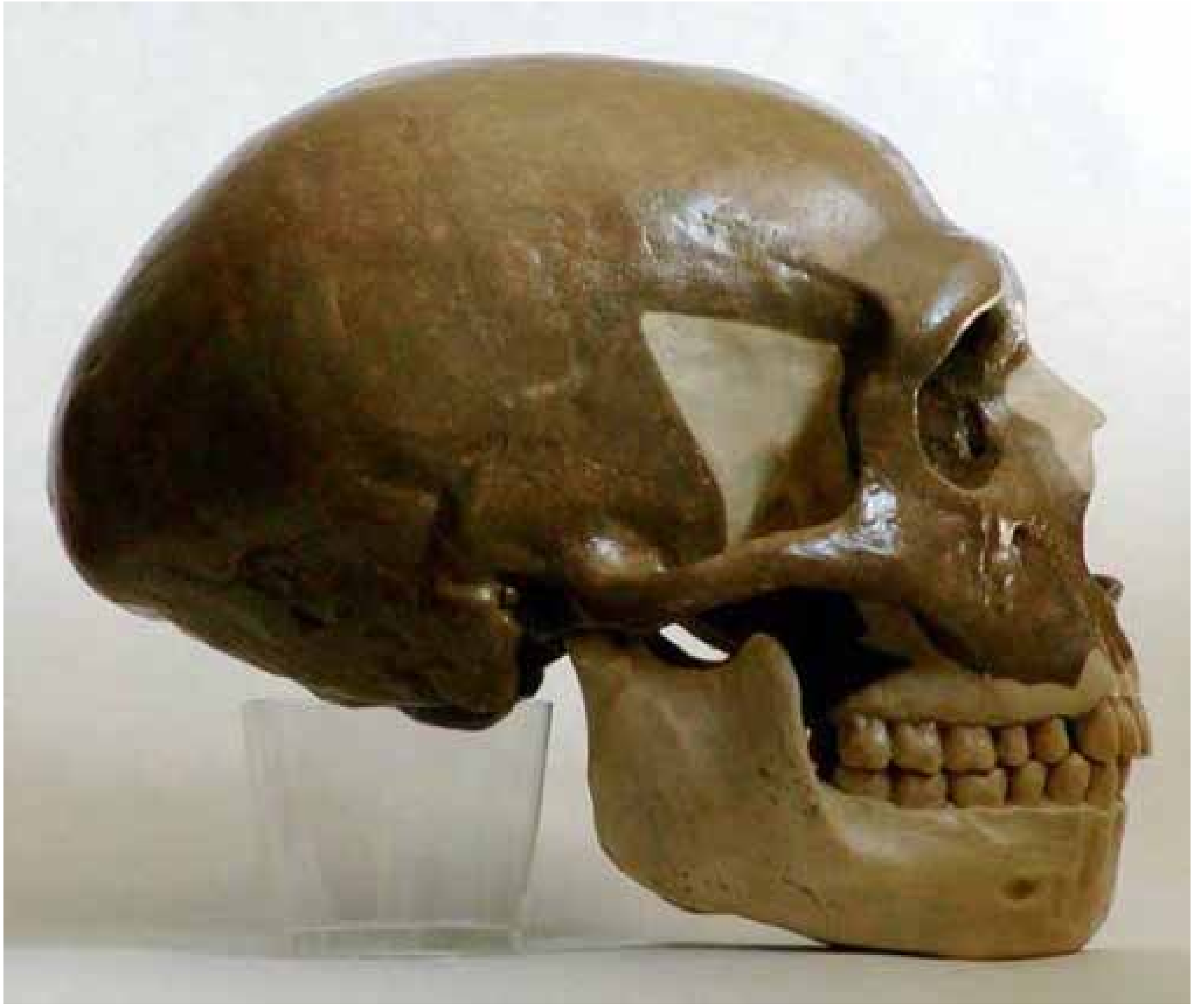
RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

Foramen Magnum Position (CD/CE * 100) = (____________ / ___________)* 100 = _____________

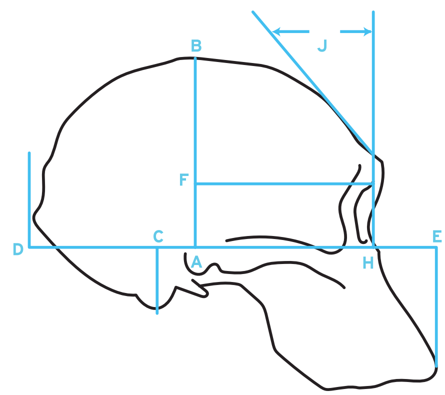
Brain height Index (BF/AB * 100) = (____________ / ___________)* 100 = _____________

Prognathic Index (EH/DE * 100) = (____________ / ___________)* 100 = _____________

Forehead slope angle = ________________________________



MEASUREMENTS SKULL #6



Line AB: ____________________mm Line BF: ____________________mm

Line CD: ____________________mm Line CE: ____________________mm

Line DE: ____________________mm Line EH: ____________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

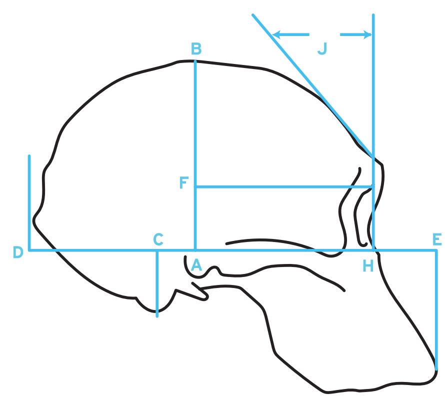
Foramen Magnum Position (CD/CE * 100) = (____________ / ___________)* 100 = _____________

Brain height Index (BF/AB * 100) = (____________ / ___________)* 100 = _____________

Prognathic Index (EH/DE * 100) = (____________ / ___________)* 100 = _____________

Forehead slope angle = ___________________________________

MEASUREMENTS SKULL #7



Line AB: ____________________mm   Line BF: ____________________mm

Line CD: ____________________mm   Line CE: ____________________mm

Line DE: ____________________mm   Line EH: ____________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

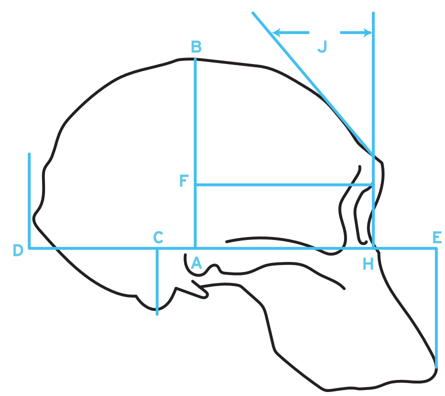
Foramen Magnum Position (CD/CE * 100) = (____________ / ____________)* 100 = ____________

Brain height Index (BF/AB * 100) = (____________ / ____________)* 100 = ____________

Prognathic Index (EH/DE * 100) = (____________ / ____________)* 100 = ____________

Forehead slope angle = ______________________________

MEASUREMENTS SKULL #8



Line AB: ____________________mm Line BF: ____________________mm

Line CD: ____________________mm Line CE: ____________________mm

Line DE: ____________________mm Line EH: ____________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

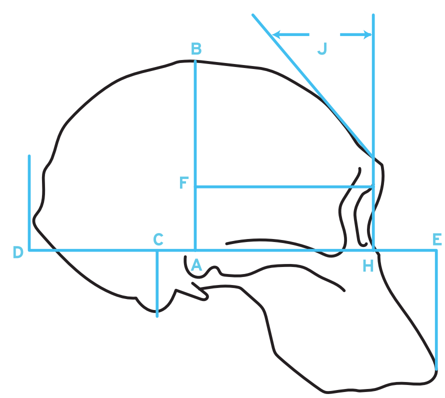
Foramen Magnum Position (CD/CE * 100) = (____________ / ____________)* 100 = ____________

Brain height Index (BF/AB * 100) = (____________ / ____________)* 100 = ____________

Prognathic Index (EH/DE * 100) = (____________ / ____________)* 100 = ____________

Forehead slope angle = ________________________________

MEASUREMENTS SKULL #9



Line AB: ______________________mm   Line BF: ______________________mm

Line CD: ______________________mm   Line CE: ______________________mm

Line DE: ______________________mm   Line EH: ______________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

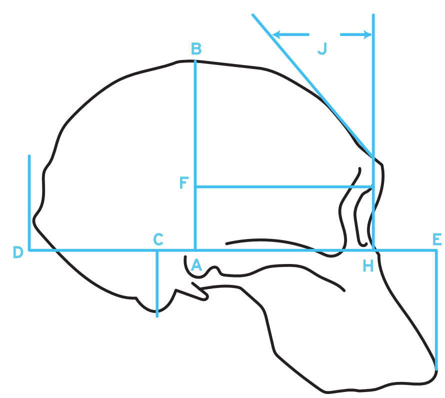
Foramen Magnum Position (CD/CE * 100) = (______________ / _____________)* 100 = _______________

Brain height Index (BF/AB * 100) = (______________ / _____________)* 100 = _______________

Prognathic Index (EH/DE * 100) = (______________ / _____________)* 100 = _______________

Forehead slope angle = ____

MEASUREMENTS SKULL #10



Line AB: ______________________mm

Line BF: ______________________mm

Line CD: ______________________mm

Line CE: ______________________mm

Line DE: ______________________mm

Line EH: ______________________mm

RATIOS FOR THIS SPECIMEN (*round to the nearest whole percent*)

Foramen Magnum Position (CD/CE * 100) = (______________ / _____________)* 100 = _______________

Brain height Index (BF/AB * 100) = (______________ / _____________)* 100 = _______________

Prognathic Index (EH/DE * 100) = (______________ / _____________)* 100 = _______________

Forehead slope angle = _______________________________________

FOLLOW UPS ONCE YOU'VE CALCULATED VARIOUS INDICES FOR THE SKULLS:

1. Research the ages of each species and their geographic locations.
2. How does each trait seem to change over time?
3. Scatter plot each species on a graph for each trait. Do any traits seem to show a correlation between "modern" species and more ancient species?
4. What traits are not covered in this lab that might also be useful to determine the lifestyles of these organisms?

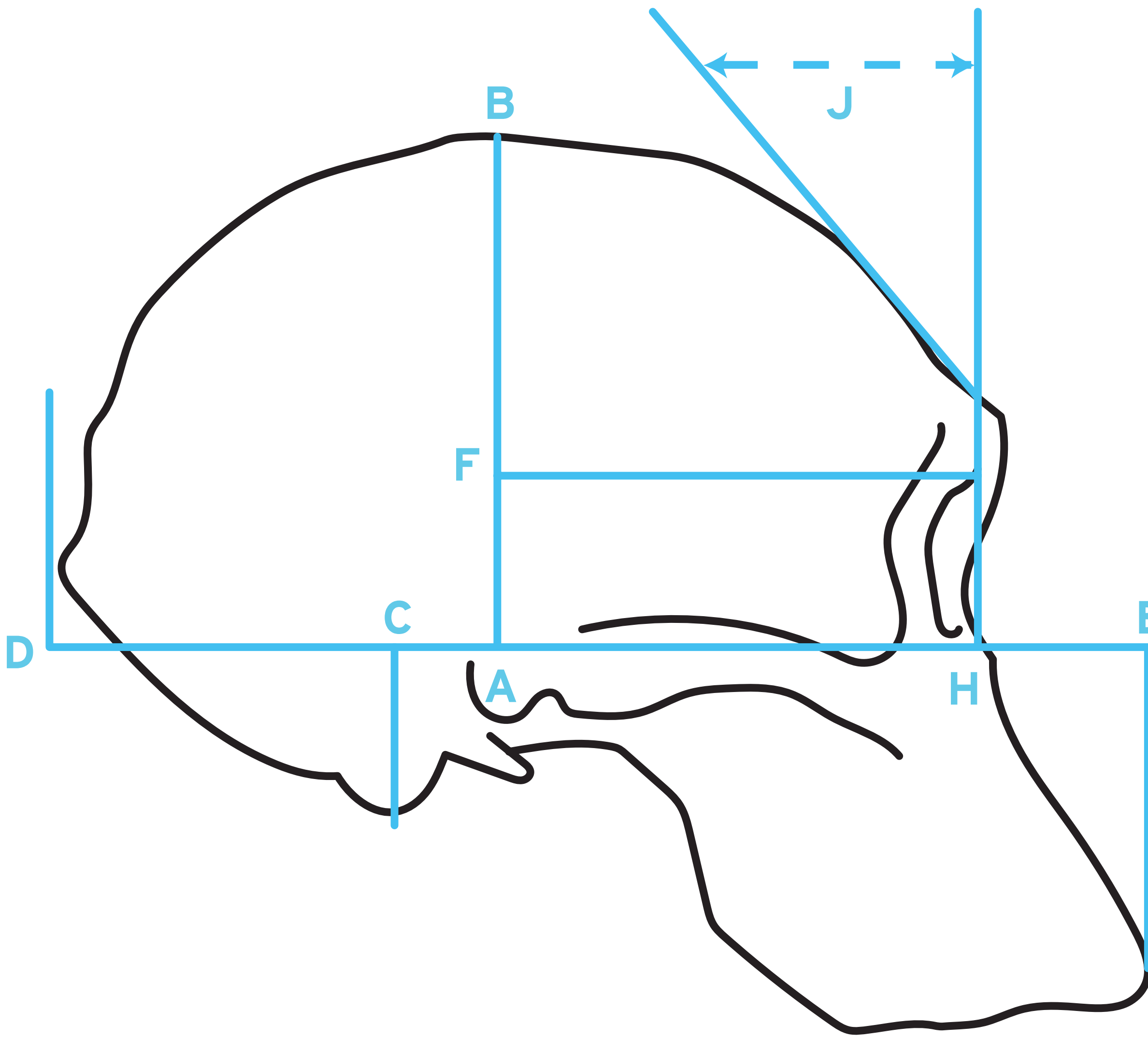
FOLLOW UPS ONCE YOU'VE CALCULATED VARIOUS INDICES FOR THE SKULLS:

- **Skull # 1**: *Homo sapiens* (Modern Human)
- **Skull # 2**: *Pan troglodytes* (Chimpanzee)
- **Skull # 3**: *Homo erectus* (Java Man / Turkana boy)
- **Skull # 4**: *Australopithecus africanus* (Mrs. Ples / Adult version of the Taung Child)
- **Skull # 5**: *Paranthropus boisei* (Zinj / Nutcracker man)
- **Skull # 6**: *Homo neanderthalensis* (Neanderthal man)
- **Skull # 7**: *Homo sapiens* (Cro – Magnon – early modern human)
- **Skull # 8**: *Homo naledi* (Dinaledi chamber)
- **Skull # 9**: *Australopithecus sediba* (Karabo)
- **Skull # 10**: *Homo naledi* ("Neo" from the Lesedi chamber)

SUBMITTED BY

John Mead
St. Mark's School of Texas

ENLARGED FACIAL GRID FOR PROJECTION / PRINTING



ACTIVITY 5 – #DINALEDIVR CLASSROOM ACTIVITY

INTRODUCTION

- Grades 3–5
- Estimated time: 60 minutes; 15–30 minutes post-field trip discussion
- Essential Question: How do archaeologists systematically excavate a site? How can we learn about people in the past (or present) by studying the things they left behind?

LEARNING OBJECTIVES

Students will be able to:

- Plan and design a research protocol to answer a scientific question
- Record and analyze archaeological data
- Make interpretations based on observed patterns in data

VOCABULARY

1. Archaeology
2. Artifact
3. Excavation
4. Site

MATERIALS PER GROUP

- Virtual reality headsets
- #DinalediVR virtual reality program (for classroom or during a field trip at the Perot Museum of Nature and Science)

Option 1 – Archaeological teaching materials

- Casts of animal bones
- Casts of human bones
- Modern ceramics (broken into pieces)
- Arrowhead replicas
- Printed pictures of cave paintings or ancient writing available on Wikimedia Commons

Option 2 – Assorted objects associated with a particular group of people (e.g. college students, teenagers in the early 2000s, etc). See "Procedure" section for suggestions

MATERIALS PER STUDENT

- Pencil
- Clipboard
- Graphing Paper (Optional)

SUBMITTED BY

Andrew Montgomery
Science Communication and Outreach Fellow
Center for the Exploration of the Human Journey
Perot Museum of Nature and Science

TEKS

Science Content

5.7D Identify fossils as evidence of past living organisms and the nature of the environments at the time using models

Science Investigation and Reasoning

3.2D Analyze and interpret patterns in data to construct reasonable explanations based on evidence from investigations

4.2D Analyze data and interpret patterns to construct reasonable explanations from data that can be observed and measured

5.2D Analyze data and interpret information to construct reasonable explanations from direct (observable) and indirect (inferred) evidence

PROCEDURE

Before your students experience the #DinalediVR Virtual Reality program, introduce them to the concept of archaeological fieldwork by completing the activity outlined below. Note that there are two options for this lesson depending on available classroom materials. Materials provided will change the discussion and the findings, but the procedure/methodology will remain largely the same. For option 1, set up stations as described below with the archaeological teaching materials.

- Casts of animal bones
- Casts of human bones
- Modern ceramics (broken into pieces)
- Arrowhead replicas
- Printed pictures of cave paintings or ancient writing available on Wikimedia Commons. For Texas examples, see Shumla Archaeological Research & Education Center

For Option 2, follow these instructions:

Identify a population of people, and set up five stations with materials that they likely use/d. For instance, if your population is college students, you may set up five stations with:

- College textbooks
- Ramen noodles
- Clothing with university logos
- Campus maps and brochures about classes and programs
- Starbucks receipts

If you choose to build an "archaeological" site that was left behind by people in the early 2000s, you may set up five stations with:

- Books, magazines, and newspapers from the early 2000s
- Popular toys from the early 2000s
- CDs from the early 2000s
- Posters with bands that were popular in the early 2000s
- Old cellphones, portable CD players, and other electronics that were new in the early 2000s

Base your "population" on the materials that are available to you. It can be as simple as setting up an archaeological site left behind by the classroom down the hall or a re-interpretation of the items that are already in the classroom. If archaeologists were to find this classroom in 2,000 years, what would they think of our society? What would they assume that we did? What would they think was important to us?

SET UP

Gather archaeological teaching materials (Option 1), or other objects (Option 2) and place them in five "stations" throughout the classroom. Pair like materials together (e.g. all hunting tools in one station, all animal bones in one station, etc.) Depending on space and classroom layout, either "hide" the materials in drawers, bookshelves, etc. or place the materials in shoeboxes.

CLASSROOM PROCEDURE

1. As students enter the classroom, inform them they are entering an archaeological site. Today in class, they will excavate the site and see if they can understand more about the people that used to live here. Their mission is to find out (1) who used to live here and (2) what their lives were like.

2. Briefly review relevant concepts and vocabulary. Definitions are listed below.

3. Divide students into groups of 3–5, and inform them that their evidence is hidden around the classroom. Give them five minutes to come up with a strategy for excavating the site. Explain to students that they will need to gather as much information about the objects that they find because that is all of the evidence they will have.

4. Instruct each group to begin at their station, and give them 5–7 minutes to excavate the objects that they find. After 5–7 minutes, have students rotate to their next station.

DISCUSSION GUIDING QUESTIONS

- What evidence did you find?
- Based on what you found, who do you think lived here? Why? What do you think their lives were like? Why?
- What other evidence would you need to be more sure?
- Are there any tests that you could do to learn more about this group?
- Was your excavation strategy effective? What were some ways that it could have been improved?

Inform students that during their field trip, they will get to see what it is like to excavate an archaeological site with the #DinalediVR experience. Ask them to think about their excavation in relation to the one they will experience in the VR headsets.

POST-VR EXPERIENCE DISCUSSION

- How did the team that discovered *Homo naledi* find these fossils? How did their excavation strategy differ from yours?
- What did they find? How do they know?
- What additional evidence would help them learn more about this species?

EXTENSIONS

1. Students can gain practice in graphing by producing a histogram of the items found during their excavation.

2. Students can perform additional research on the *Homo naledi* find. What have scientists postulated about this species' behavior? What evidence did the scientists use to draw this conclusion?

DEFINITIONS

Archaeological Site – Any place where human material remains are found; an area of human activity represented by material culture.

Archaeology – The scientific excavation and study of ancient human material remains.

Artifact – A portable object manufactured, modified, or used by humans.

Excavation – The digging up and recording of archaeological sites, including uncovering and recording the provenience, context, and three-dimensional location of archaeological finds.

ACTIVITY 6 – WHERE AM I SUPPOSED TO DIG?

INTRODUCTION

- Grades 3–8
- Estimated time: 20–30 minutes
- Essential Question: How do archaeologists decide where to excavate? What are the basic principles of archaeological fieldwork?

LEARNING OBJECTIVE

- design a survey and excavation procedure for a mock paleoanthropological find

VOCABULARY

1. Anthropology
2. Archaeology
3. Artifact
4. Context
5. Ecofact
6. Excavation
7. Hominin
8. Site
9. Survey
10. Unit

MATERIALS PER GROUP

1. Graphing Paper
2. Pencils
3. Rulers
4. *With Extension – Painter's Tape and Measuring Tape

MATERIALS PER STUDENT

1. Graphing Paper
2. Pencil
3. Ruler

TEKS

Science Investigation and Reasoning

6.2B Design and implement experimental investigations by making observations, asking well defined questions, formulating testable hypotheses, and using appropriate equipment and technology;

7.2B Design and implement experimental investigations by making observations, asking well defined questions, formulating testable hypotheses, and using appropriate equipment and technology;

8.2B Design and implement experimental investigations by making observations, asking well defined questions, formulating testable hypotheses, and using appropriate equipment and technology

PROCEDURE

Day 1: Introduce students to the topic: Finding a hominin fossil in the ground is exceptionally rare.

Of all of our human ancestors that once walked Earth, the remains of only a select few have managed to evade millennia of natural processes that threaten their preservation. These bones that do survive and enter the archaeological record are small, scarce, and sometimes underground. Paleoanthropologists also find fossils that are visible on the surface from erosion. Even though the odds are not in their favor, paleoanthropologists continue to generate new finds and new information about our human past.

Where do they find these fossils? How do they decide where to search? How do they decide where to excavate? Once they do determine where the fossils might be, how and where do they dig the holes?

1. Inform students that some school employees have reported some very interesting rocks on the playground (or soccer field, school yard, parking lot, etc.). They think that the rocks may be bone, but they are unsure. They also do not remember where they found these rocks. There have been rumors of ancient hominin fossils on this school property, but no real evidence exists besides a couple of second-hand accounts.

2. Explain to your students that they need to come up with a plan to find these potential bones and determine whether or not they are fossil material. They will need to be very organized, collaborative, and efficient to locate the material before time (funding) runs out.

3. Divide students into groups of 3-5 and tell them to come up with a plan. How will they find potential areas to excavate? How will they split up? Who will cover which areas? When they decide where they might want to dig, how will they do it? Which tools will they use? Provide graph paper for students to plot out a survey plan for the designated area.

EXTENSION

*If you have space available, actually place a 3D printed bone (or a substitute item) on the playground or soccer field, and have students implement their plan. Instruct students to place tape on the soccer field over the places that they would like to excavate. Time them to see if they can locate the bone and convince their funders that there is a need for further study and excavation.

SUBMITTED BY

Andrew Montgomery
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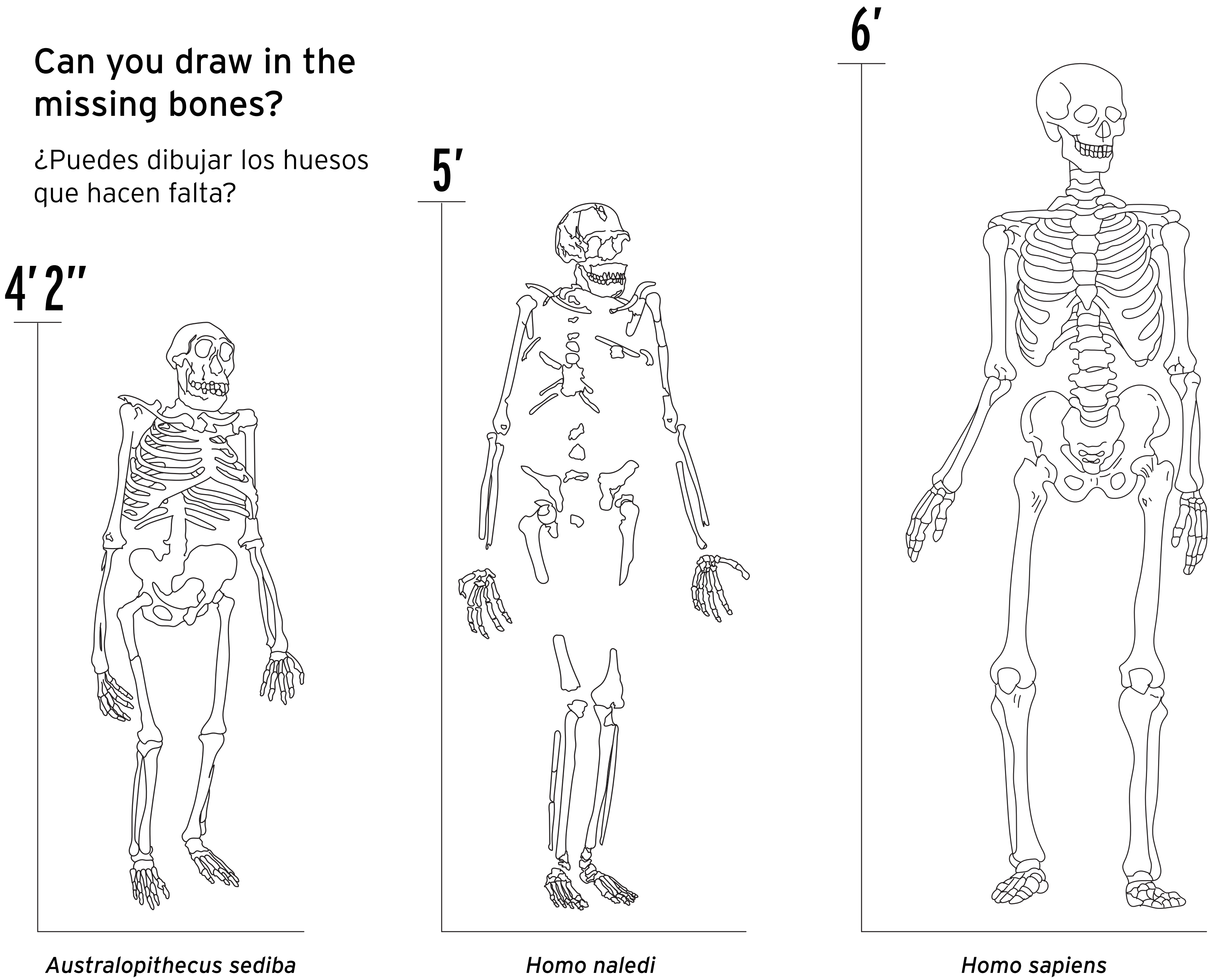
Center for the Exploration of the Human Journey
Perot Museum of Nature and Science

ORIGINS Fossils from the Cradle of Humankind

Perot Museum of Nature and Science

Can you draw in the missing bones?

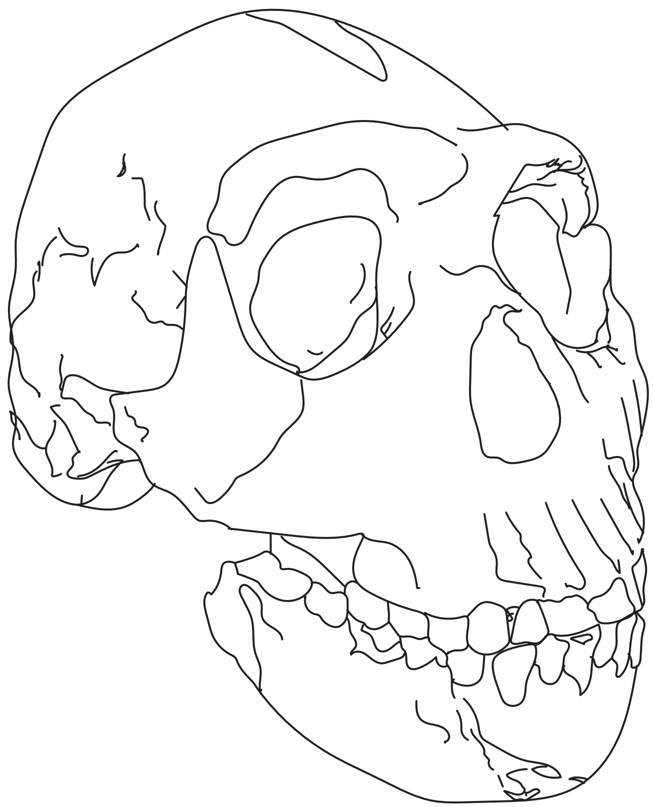
¿Puedes dibujar los huesos que hacen falta?



ORIGINS Fossils from the Cradle of Humankind

Perot Museum of Nature and Science

Meet Neo
Conoce a Neo

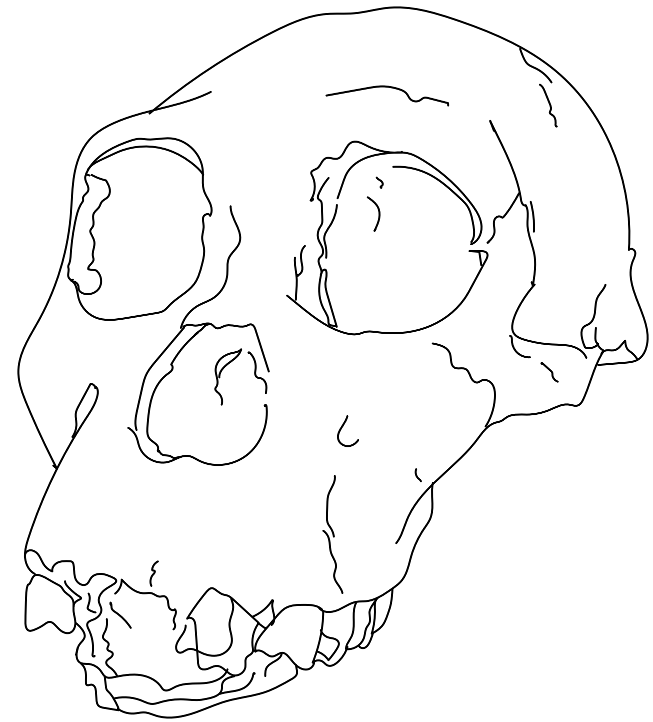


- **Neo "gift"**
  Neo significa "regalo"
- ***Homo naledi***
- **Lived 300,000 years ago**
  Vivió hace 300,000 años
- **Discovered in 2013**
  Se descubrió en 2013
- **Found in Rising Star Cave, South Africa**
  Fue encontrado en Rising Star Cave, Sudáfrica

Africa
África

Map of South Africa
Mapa de Sudáfrica

Meet Karabo
Conoce a Karabo



- **Karabo "answer"**
  Karabo significa "respuesta"
- ***Australopithecus sediba***
- **Lived 1.97 million years ago**
  Vivió hace 1.97 millones de años
- **Discovered in 2008**
  Se descubrió en 2008
- **Found at Malapa, South Africa**
  Fue encontrado en Malapa, Sudáfrica