NOVA

Bones of Contention

Student Worksheet

INTRODUCTION

In this activity, you will explore a database that provides information about 60 fossils of *hominins*, the biological classification consisting of modern humans and chimpanzees, extinct human species, and all our immediate ancestors. In addition to fossil records, the database includes for the purposes of comparison 8 records of contemporary *hominids*, the biological classification consisting all modern and extinct Great Apes.

While you can use the database independently to discover information about various hominin species, this guide leads you through an activity in which your task is to identify up to 10 mystery fossils, either by suggesting new species classifications—that is, biological groupings— or by matching each with a known species. Your teacher will give you instructions on which parts of this activity you or your group should work on.

Note that some of the mystery fossils do not have matching species in the database, so keep an eye out for fossils that could represent unique species discoveries!

When scientists try to determine how to place a fossil in the human evolutionary tree, they focus on several key characteristics:

- Was the creature bipedal? (Did it walk on two legs?)
- Do its teeth and jaws indicate that its diet consisted of harder or softer foods?
- How large was its brain?

In each of the sections below, you'll set up different filters to view fossils records that provide particular types of evidence, so that you can develop ways to compare the mystery fossils to known records.

You will face many of the same challenges scientists encounter:

- Species are not always found chronologically
- Sometimes fossils present conflicting evidence
- Fossil records are often incomplete

To begin, open the Bones of Contention interactive. Read, and then close, the instructions. You're now ready to explore the database.

PART A. LOOKING AT EVIDENCE OF BIPEDALISM

Bipedalism can be used to separate the earliest human ancestors from the ancestors of early apes. There are two types of evidence of bipedalism: *cranial* evidence (skull fragments) may show the position of the *foramen magnum* (the place where the spine enters the skull), and *post-cranial* evidence (fragments from other parts of the body) may show the shape and position of the pelvis, femur, shinbones and finger bones, as well as the relative lengths of the limbs (arms and legs).

Note that very few fossils have both cranial and post-cranial data, so to identify the earliest bipeds, you have to do separate analyses of cranial and post-cranial data.

1. **Group cranial records for earliest fossils based upon foramen magnum position:**
   a. Read about foramen magnum position by clicking on the "i" next to that category. (You can find the category in the data table or click "Edit Columns..." for the full list of categories.)

Filter out non-bipeds

   b. Non-bipeds (such as modern apes) have foramen magnum positions toward the back of their skulls. Note that the earliest bipeds may have foramen magnum positions that are slightly more forward than non-bipeds, but still far back enough to be considered "back of skull." Start by filtering records in which the foramen magnum position is toward the back of the skull.
      - Select Field: Foramen Magnum Position
      - Select Comparison: equal to
      - Select Value: Back of Skull
      - Click: Add Filter

   c. Note that the filtered records include one very old record and several contemporary records of modern apes. You can remove the modern apes from this group with a date filter. The date refers to "number of years ago," and is generally based upon the layer of sediment in which the fossil was found.
      - Select Field: Date
      - Select Comparison: greater than
      - Select Value: 0
      - Click: Add Filter
      - Save your species, giving your group a name that describes what you have found, such as "Pre-biped".

   d. You have created a group that contains your first mystery fossil! Double click on the mystery fossil record to see the fossil's details. Give it a name that helps you distinguish it based on its characteristics and record it in the space below.

RECORD THE MYSTERY FOSSIL HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

Group early bipeds

e. Bipeds are likely to have foramen magnum positions toward the middle of their skulls. Find the records in which the foramen magnum position is toward the middle of the skull.
   - Using the same methods described earlier, create a filter for fossils for which the foramen magnum position is the middle of the skull.
   - Narrow your group further by filtering this group for the oldest fossils—say, only those fossils 3 million years or older (greater than or equal to 3,v000,000).
   - Save this "species" group and give it a name that describes the group.
   - If your new group contains any mystery fossils, compare them to other fossils in the group in order to create a descriptive name or an actual species name. Record your names in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

f. Optional: What happens if you change the date filter to "greater than" 2 million years ago? How would you divide this larger group?

2. Group post-cranial records for earliest bipeds:

There are several post-cranial features that imply bipedalism: (a) femur orientation (angled inward), (b) the largest limb (lower limb), (c) the shape of the pelvis, (d) the size and shape of the shin, and (e) the shape of finger bones.

a. Click "Edit Columns" and select to display Femur Orientation, Largest Limb, Pelvis Shape, Finger and Toe Bones, and Shin Bone Malleolus. Read about these features by clicking on the "i" next to each category.

Tip: To save screen space, you can hide columns you don't need by clicking the "x" in the column headers.

b. Sort the data table according to Femur Orientation by clicking on the column header. Based on the information available, what sorts of records are *not* bipedal?

c. Create a filter for Femur Orientation that shows bipeds.
   - Use the same filtering methods described earlier.
   - Compare the characteristics across the fossils in this group. Based on available data, what similarities do they share? Do any fossils stand out as being different? Are any of the features inconsistent with the others?

d. Since we are looking for the earliest bipeds, refine this group so that you see only fossils older than 2 million years ago.
   - If you already saved the group, find it in your groups list and click "edit"
   - Once you filter for fossils older than 2 million years, are their any outliers that do not belong in this group? If so, add a filter that removes this outlier.

- Rename your group with a more descriptive name.

e. If your new group contains any mystery fossils, compare them to other fossils in the group in order to create a descriptive name or an actual species name for the mystery fossil(s). Record your names in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

Analysis Questions for Part A:

1. What is the difference between cranial and post-cranial fossils?
2. Based on the available evidence, what creature do you think was the earliest biped?
3. What is the earliest sign of large leg bone? Next after that?
4. In addition to femur orientation, which features proved useful in helping you narrow your group(s)?
5. Are there any fossil records in your groups of cranial and post-cranial bipeds that might be the same species? Why?

PART B. DIET: HOW CHEWING IMPACTS THE SKULL

Traits such as cranial capacity (volume of the skull) and skull characteristics that give clues about diet can help anthropologists classify separate species of human ancestors.

Some hominins developed larger teeth, massive jaw muscles, and more robust skulls, indicating that they chewed harder foods. These features are indicated by cresting (bony projections on the skull for muscle attachment), dish-like or jutting-out face shape, and post-orbital constriction (a narrowing of the skull behind the eyes that is related to smaller brain size). Other hominins with a softer diet developed smaller molars and faces, less robust skulls, and with that, larger brain sizes.

1. **Group cranial records for harder diets**
   a. Click "Edit Columns" and select to display Cresting, Dentition, Face Shape, Post-orbital Constriction and Cranial Capacity. Read about these features by clicking on the "i" next to each category.
   Tip: To save screen space, you can hide columns you don't need by clicking the "x" in the column headers.
   b. Create a group of fossils that likely lived off a diet of hard foods. Filter for Cresting=large. Compare the different characteristics across the fossils in this group.
   c. Use additional filters to refine your group based on additional diet-describing categories in order to eliminate outliers.
      - Based on available data, other than cresting, what similarities do they share?
      - Do any fossils stand out as being different?
      - Are any of the features inconsistent with the others?
   d. Add a filter for dentition=megadontia, the largest molar size.
   e. Save this group and give it a name that describes the type of diet of the group.
      - If your new group contains any mystery fossils, compare them to other fossils in the group in order to create a descriptive name or an actual species name. Record your name(s) in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

2. **Group Records for Softer Diets**
   a. Next, let's create a group based on a more human-like diet.
      - Filter for Cresting=none.
      - Sort by small molars.
      - Get rid of contemporary records by creating a date greater than zero.
      - What are the key differences among the remaining fossils?
   b. Create separate groups based on face shape. Give each group a descriptive

name.

- Which one is more primitive?

c. If your new groups contain any mystery fossils, compare the mystery fossils to other fossils in the group in order to create a descriptive name or an actual species name. Record your name(s) in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

Analysis Questions for Part B:

1. Describe what/how cranial features can tell us about a hominin's diet.
2. Why is diet significant? What can it tell us about a species?
3. Looking over the groups you created, what are the differences in cranial capacity between groups with hard diets vs. those with a less robust chewing complex/features related to a softer diet? (You may need to show the column for "Cranial Capacity".) Describe this relationship.
4. Compare the dates of the groups you created based on diet— particularly those with a hard diet and the earlier species with a soft diet. Do you notice any overlap in when they lived? What does this tell you about the possible relationship between these species?

PART C. BRAIN SIZE AND COGNITIVE ABILITY

An important characteristic of hominin evolution is cognitive ability—how intelligent the creature was. Scientists often use cognitive ability to differentiate between the most recent human ancestors.

One seemingly obvious sign of increasing cognitive ability is brain size. Aside from cranial capacity (estimate of brain size), other key signatures of brain size are: post-orbital constriction (a narrowing of the skull behind the eyes that is related to smaller brain size), brow size (size of the bony projection over eyes where the eyebrows lie) and cresting (bony projections on the skull for muscle attachment).

However, brain size is not always a precise indicator of evolutionary advancement.

Another sign of cognitive ability is the use of tools. As hominins got smarter, their tools became more sophisticated (evolving from asymmetrical, to symmetrical, to shafted, to metal). Likewise, increased tool use probably supported hunting of meat and grinding of plant products, thus providing energy needed to support larger brains.

1. **Brain Size & Tool Use**
    a. Click "Edit Columns" and select to display Cranial Capacity, Post-orbital Constriction, Brow Size, Cresting, and Tools. Read about these features by clicking on the "i" next to each category.

Tip: To save screen space, you can hide columns you don't need by clicking the "x" in the column headers.

    b. Create a group of fossils that represent the most cognitively developed (i.e., the most intelligent) human ancestors. Filter for Cresting = none (cresting is a common characteristic of small-skulled hominins).
    c. Compare the different characteristics across the fossils in this group.
        - Based on available data, other than cresting, what similarities do they share?
        - Do any fossils stand out as being different?
        - Are any of the features inconsistent with the others?
    d. Try sorting by Cranial Capacity. Does this help group fossils or not? Why or why not?

Note that cranial capacity of 0 in the database means that such data is not available for this fossil.

    e. Add a filter for Post-orbital constriction = minimal.
        - What genus or genera (plural) are represented among the fossils remaining in your group?
    f. Now, further group your remaining fossils according to the type of tools they most likely used.
    g. If your new groups contain any mystery fossils, compare the mystery fossils to other fossils in the group in order to create a descriptive name or an

actual species name. Record your name(s) in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

Group the most intelligent hominins.

h. Scientists think post-orbital constriction plays a large role in intelligence. Why?
i. Create a new group where post-orbital constriction = none.
    - Based on available data, other than post-orbital constriction, what similarities do they share?
    - What are the key differences?
j. Create separate groups based on the remaining categories. Give each group a descriptive name.
k. If your new groups contain any mystery fossils, give them descriptive name(s) or an actual species name(s) based on other fossils in their groups. Record your names in the space below.

RECORD ANY MYSTERY FOSSILS HERE:

Mystery ID	Create a descriptive name for the fossil or guess the species name

Analysis Questions for Part C:

1. What role do cresting and post-orbital constriction have in determining brain size?
2. According to this database, what is the earliest species to use tools? What makes this fossil similar or different from others like it?

Note: The tool data in this database provides just an indicator of tools most commonly associated with each species. In fact, some evidence exists for primitive tool use in earlier species, though this is subject to scientific debate.

3. Who were the earliest users of symmetrical tools? What else do you notice about species that used symmetrical tools?
4. Why is cranial capacity a deceptive indicator of evolutionary advancement?
5. Provide an explanation for the rapid growth in brain size in the most recent human ancestors.
6. Taking it Further: Thought the purpose of the nasal margin is unclear, it is a clear species differentiator. Examine fossils according to Nasal Margin and describe how that characteristic helps differentiate species.

CONCLUSION: FINAL MATCHING

1. If your class divided into groups for this activity, share findings across groups

a. Your teacher will ask each group to share its findings with the entire class.
   - When presenting, use the groups you created and saved in the tool to describe which features you used to define each of your mystery fossils.
   - Optional: The teacher may ask you to print your groups for your presentation.
   - When listening, take notes on a separate sheet of paper, recording the key characteristics for each fossil.

b. Each group presentation should include the following points. Also, each student in the audience should take notes on the same points.
   - What characteristics the group was investigating
   - The name given to the mystery fossil
   - The features were used to identify the fossil
   - What each feature means and what it tells us about the fossil.

2. If you have done all of the sections of this activity, revise & refine your groups

a. If you have done all of the sections of this activity, revisit your mystery fossils, refining and renaming each of them based on your full knowledge of the indicators of bipedalism, diet, and cognitive ability.
   - Review the list of saved groups that you created. Now that you know more about indicators for bipedalism, diet, and cognitive ability, revise your groups using any available data. For instance, look at your groups of bipeds in light of cognitive ability or diet to see if you can further refine them.
   - Review the names you gave each group. Revise them as necessary using the "edit" links in the saved group list.

3. Print your groups (all students)

a. When you are ready, print your groups list.
   - Ask your teacher whether to print your list on a printer or save the print window as a pdf file (this will depend on your classroom's computer setup).

4. Record your final mystery fossil classifications (all students)

a. In the space below write down your final fossil classifications, and the key evidence supporting the classification.
   - If your class divided the work, use your notes from the presentation, along with your own findings, to complete the list of mystery fossils.
   - If you did the entire activity, use your revised groups to verify and revise your mystery fossil classifications.

b. If you think you have a match to a species in the database, note that as well. If not, create a name for the fossil that accurately describes its key qualities.

c. If you changed your classification from your original finding, explain why. DO NOT ERASE OR CROSS OUT THE FOSSIL CLASSIFICATIONS YOU WROTE IN THE PAGES ABOVE! Changing your original answer may be part of the process.

MYSTERY FOSSILS (REVISED LOG):
(mya= million years ago; ya= years ago)

Mystery ID	Date	Descriptive name or species classification	Key Evidence
1	6-7mya		
2	2.9-3.3 mya		
3	3mya		
4	2.5mya		
5	1.8mya		
6	1.7mya		
7	1.51-1.56 mya		
8	220,000-580,000 ya		
9	150,000-250,000 ya		
10	40,000 ya		

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