Evolutionary Relationships
HASPI MS Medical Life Science Lab 10
MS-LS4-1, MS-LS4-2, MS-LS4-3

Introduction

Common Descent
Universal common descent was first proposed by Charles Darwin in On the Origin of Species in 1852. It is the theory that all living things on Earth evolved over many generations from a single common ancestor and is universally accepted throughout the scientific community. In fact, evidence suggests that the Last Universal Common Ancestor (LUCA), or most recent organisms from which all living organisms on Earth have evolved from, is a single cell that lived 3.5 to 3.8 billion years ago.

Since Charles Darwin proposed his theory of evolution, scientists have found a great deal of evidence that supports his claim. Similar body structures, patterns of early development, molecular structure, and fossils all provide evidence that organisms have changed over time.

Comparative Anatomy
The theory of evolution predicts that organisms that are closely related will display similarities. In fact, early evolutionary relationship theories were solely based upon observations of similarities between organisms. The comparison of the body structures of different organisms is called comparative anatomy. Fishes, amphibians, reptiles, birds, and mammals for example all have an internal skeleton with a backbone. All of these animals probably inherited this trait from an earlier ancestor, leading scientists to classify all five groups as vertebrates.

The image to the left shows the similarities in skeletal arrangement of the limbs of a few different animals. These similar structures are known as homologous structures and provide evidence that these organisms all evolved from a common ancestor.

Genetic Similarities
The structure of an organisms’ genetic material also provides evidence for evolution. An individual’s physical traits, or phenotype, are a direct result of its genetic makeup, or genotype. By comparing the genes or DNA, RNA, amino acid sequence, and cellular structure, scientists can infer evolutionary
relationships. If two organisms have molecular structures that are similar, it makes sense that they are closely related. On the other hand, if two organisms have molecular structures that are very different, they must have diverged evolutionarily a much longer time ago.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>% Identical DNA</th>
<th>SPECIES</th>
<th>% Identical DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans</td>
<td>99.9</td>
<td>Chicken</td>
<td>65</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>93</td>
<td>Fruit Fly</td>
<td>47</td>
</tr>
<tr>
<td>Mouse</td>
<td>88</td>
<td>Honey Bee</td>
<td>44</td>
</tr>
<tr>
<td>Cow</td>
<td>85</td>
<td>Round Worm</td>
<td>38</td>
</tr>
<tr>
<td>Dog</td>
<td>84</td>
<td>Wine Grape</td>
<td>24</td>
</tr>
<tr>
<td>Zebra Fish</td>
<td>73</td>
<td>Baker’s Yeast</td>
<td>18</td>
</tr>
</tbody>
</table>

**Embryology**

Embryology is the study of the formation and development of an embryo and fetus. Scientists can make inferences about evolutionary relationships by comparing how different species develop before birth.

For example, nearly all vertebrates have similar stages of embryo development and are difficult to differentiate until much later in their growth process. The image to the right illustrates how all vertebrate embryos, including humans start with a tail and gill slits.

**The Fossil Record**

Fossils are the preserved remains or traces of animals, plants, and other organisms from the remote past. The formation of any fossil is actually a rare event and requires the right circumstances. Mold fossils form when part of an organism forms an imprint on sediment and hardens to become rock. Cast fossils form when minerals fill in the hollows of an animal track, shell, or other parts of an organism. Petrified wood forms when minerals replace the organic material in trees and fossil fuels form from the remains of dead plants and animals. In really rare circumstances, like when a bug gets trapped in tree sap or an animal gets frozen in ice or gets stuck in a tar pit, whole body fossils are preserved.

By looking closely at fossils, scientists can discover when and where certain organisms lived along the geological time scale. Scientists are able to compare the location of fossils within certain rock strata, or layers of sediment to gain an idea of how old these organisms are. The accuracy of dating fossils has dramatically improved with the advancements in radioactive dating techniques, which is based on the comparison between the abundance of naturally occurring radioactive isotopes and decay products. When looking at the whole fossil record, scientists can deduce evolutionary relationships between organisms to gain a better understanding of how each fits in the entire history of Earth.
Evolution and Medicine

Medical science is continually changing. Not only are new medications and treatments being developed, but the organisms that cause certain diseases are changing as well. Understanding evolution can make a big difference in how scientists and doctors are able to treat certain diseases. Scientists can gather clues in the fossil record, compare anatomical structures, and even pinpoint certain genetic strands and the production of key proteins in other species to understand how and why certain organism adapt and thrive. These clues not only give insight on how people get sick, but also shed light on why people get sick. Incorporating principles of evolution into medicine has already proven to be beneficial in developing strategies for minimizing antibiotic resistance and improving vaccine strategies against some of the most infectious virus strains. Evolutionary principles have also directed research in genetic engineering and the possibilities of gene therapy. By manipulating DNA, scientists are already able to genetically modify organisms to produce key enzymes and antibodies for medical treatment. Future advancements in gene therapy may allow doctors to treat disorders by inserting specific genes into a patient’s cells instead of using drugs or surgery. The image below outlines the basic principles of gene therapy.

http://landdestroyer.blogspot.com/2012/12/on-cusp-of-ending-big-pharma.html
Review Questions

1. What is the idea of common descent?
2. What does LUCA stand for?
3. What is a vertebrate? Provide examples.
5. How similar is your genetic makeup to any one of your classmates?
6. Which animal has the most genetic similarities as humans? What does this infer about the evolutionary relationship between humans and this animal?
7. Define embryology.
8. How are fossils formed?
9. How do scientists determine how old a fossil is?
10. Understanding the principles of evolution not only give insight on how people get sick, but also shed light on ___________ people get sick.
11. How can gene therapy be used to treat certain disorders?
Hominid Skull Comparisons
HASPI MS Medical Life Science Lab 10a

Introduction

Hominid, or Homidae, refers to the family of primates that includes humans and their closest relatives: chimpanzees, gorillas, and orangutans.

The image to the right illustrates the lineage from which modern day humans, Homo sapiens, have evolved. Fossil records indicate that humans branched away from their closest living relative, the chimpanzee, about 6 million years ago. In that time frame, the image also indicates that the evolution from ancient primates to modern day humans was not linear. Most scientists currently recognize some 15 to 20 different species of early humans, but do not all agree on how each species was related or which ones simply died out. It is in consensus however, that the three most recent species of hominids (Homo heidelbergensis, Homo neanderthalensis, and Homo sapiens) all evolved from an earlier species called Homo erectus.

Hominid species changed over periods of hundreds of thousands of years, adapting to new environmental conditions. In order to understand human evolution, scientists analyzed fossils they discovered, and categorized them based on similarities and differences. They were able to find trends among species and better understand how they came to be. In this activity you and your partners will examine images of fossils to find similarities and differences between different members of the hominid family.

Materials

Hominid Skull Information sheet
Hominid Skull Comparisons record sheet

Directions

<table>
<thead>
<tr>
<th>Task</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Obtain the 7 Hominid Skull Information sheets from your teacher.</td>
<td><img src="http://mediamilitia.com/wp-content/uploads/2010/10/skulls-600-7.jpg" alt="Image" /></td>
</tr>
<tr>
<td>2 Read the information provided and examine the images of each skull very carefully.</td>
<td></td>
</tr>
<tr>
<td>3 As you read the information and examine each picture provided for each hominid, complete the Hominid Skull Comparison record sheet.</td>
<td></td>
</tr>
</tbody>
</table>
Summarize your findings in the table below. For each trait, characterize the condition in Modern Human and Modern Chimpanzee. For each of the other species, indicate whether each trait is more ape-like (A) or more human-like (H). Add up all the A’s and H’s in each column and place their respective totals in the spaces below.

<table>
<thead>
<tr>
<th>Skull Trait</th>
<th>Homo Sapiens (Modern Human)</th>
<th>P. troglobdytes (Modern Chimpanzee)</th>
<th>Au. boisei</th>
<th>Au. Africanaus</th>
<th>Homo erectus</th>
<th>Homo neanderthalensis</th>
<th>Homo sapiens (Cro-magnon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranium Size</td>
<td>1215ml (m) 1375 ml (f)</td>
<td>300-500 ml</td>
<td>A</td>
<td>A</td>
<td>A/H?</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Forehead Shape</td>
<td>Vertical</td>
<td>Flat</td>
<td>A</td>
<td>A</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Foramen Magnum Position</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Browridge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasal Bone</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chin Shape</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Dental Arcade Shape</td>
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<td></td>
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<tr>
<td>Incisor Angle</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Canine Diastema</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canine Protrusion</td>
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<tr>
<td><strong>Total Ape-Like Traits</strong></td>
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<tr>
<td><strong>Total Human-Like Traits</strong></td>
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</tbody>
</table>
## Analysis Questions

1. List the species that you examined in order from oldest to youngest.
2. What overall trends did you notice amongst the skull traits as the hominid species progressed through time?
3. What features did all hominid skulls have in common?
4. Which features were most useful for distinguishing between species?
5. What is a hominid?
6. How long ago does the fossil record suggest humans diverged from apes on the evolutionary tree?
7. Why do you think it is difficult for all scientists to agree on an exact number of early human species?
# Hominid Skull Comparisons

HASPI MS Medical Life Science Lab 10a

<table>
<thead>
<tr>
<th>Homo Sapiens (Modern Human)</th>
<th>P. troglodytes (Modern Chimpanzee)</th>
<th>Au. boisei</th>
<th>Au. africanus</th>
<th>Homo erectus</th>
<th>Homo neanderthalensis</th>
<th>Homo sapiens (Cro-magnon)</th>
</tr>
</thead>
</table>

**Cranium Size**
What is the average volume of the brain cavity?

**Forehead Shape**
Does the forehead (frontal bone) look more vertical or flatter?

**Foramen Magnum Position**
The foramen magnum is the large opening in the base of the skull through which the spinal cord connects with the brain. Is the foramen magnum oriented toward the rear or towards the middle of the base of the skull?

**Browridge**
Is a supraorbital browridge (bony ridge above the eye sockets) present? If present, is the browridge divided in the middle or continuous?
<table>
<thead>
<tr>
<th></th>
<th>Homo Sapiens (Modern Human)</th>
<th><em>P. troglodytes</em> (Modern Chimpanzee)</th>
<th><em>Au. boisei</em></th>
<th><em>Au. africanus</em></th>
<th><em>Homo erectus</em></th>
<th><em>Homo neanderthalensis</em></th>
<th>Homo sapiens (Cro-magnon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nasal Bones</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Are the nasal bones raised or arched?</td>
<td></td>
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<tr>
<td><strong>Chin Shape</strong></td>
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<tr>
<td>Does the front of the lower mandible angle forward or backward?</td>
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<tr>
<td><strong>Dental Arcade Shape</strong></td>
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</tr>
<tr>
<td>Do the teeth rows diverge toward the back (form a parabola shape) or more straight-sided and parallel to one another (rectangular shape)?</td>
<td></td>
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<tr>
<td><strong>Incisor Angle</strong></td>
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</tr>
<tr>
<td>When viewed from the side, are the incisors (front row of teeth) angled out or are they vertical?</td>
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<td></td>
</tr>
<tr>
<td><strong>Canine Diastema</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is a diastema, or space or gap, present between the canine and the incisors?</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Canine Protrusion</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the canine project above the chewing surfaces of the other teeth?</td>
<td></td>
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</tr>
</tbody>
</table>
Homologous Structures
HASPI MS Medical Life Science Lab 10b

Introduction

Anatomy is the branch of biology concerned with the study of the structure of humans, animals, and other living organisms. Since the beginning of existence, the human anatomy has been studied and compared to the structures of other organisms to form one of the basic essential sciences of medicine.

Even though there is great diversity in species on Earth, there are still many similarities between their anatomical structures. These similarities provide evidence that life on Earth has a common ancient ancestor that all species have evolved from over time. Homologous structures, in particular, are parts of the body that are similar in structure to the comparative parts of other species. The more closely organisms are related, the more similar the homologous structures are, even if their functions are different.

Most examples of homologous structures revolve around the limbs of the species being compared. Mammals in particular have similar limb structures. The flipper of a whale, the wing of a bat, and leg of a cat are all very similar to the human arm. All species have a large upper arm bone (humerus) and the lower part of the limb is made of two bones (radius and ulna). Each species also has a collection of smaller bones in the wrist (carpals) that lead into the longer “fingers” (phalanges). Even though the bone structures in these limbs of the mammals are very similar, the function of the limb itself is very different as bats use their limbs for flying, cats for walking, whales for swimming, and humans for everything they do with their arms. These functions evolved through the process of natural selection as common ancestors experienced changes in their respective environments.

Originally, how species looked were the determining factor for classifying organisms. Scientists would look at analogous structures, or body parts that look the same and are used for similar functions. The wings of insects, birds, bats, and pterodactyls are examples of analogous structures. But just because the functions are very similar does not mean the species are more closely related. DNA research reaffirms the evolutionary relatedness of species with homologous structures. Bats for example, are more closely related to humans than they are to birds or insects. In this activity you and your partners will re-create the bone structures of the limbs of 4 mammals to identify similarities in homologous structures.
Materials

Homologous Structures sheet  Scissors  Tape or glue

Directions

<table>
<thead>
<tr>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

For each limb, label the different types of bones:

- Humerus
- Radius
- Ulna
- Carpals
- Metacarpals
- Phalanges

Analysis Questions

1. What is the difference between homologous structures and analogous structures? Provide examples of each.
2. Which provides stronger evidence that two species are more closely related, homologous structures or analogous structures?
3. Of the four animals in this activity (human, cat, whale, bat), which would you argue are the most closely related on the evolutionary tree? Justify your answer.
4. What causes the function of homologous structures to be different even though their structures are very similar?
Homologous Structures
HASPI MS Medical Life Science Lab 10b

Name: _____________________
Period: ____________
Date: _________

Evolutionary Relationships, HASPI MS Medical Life Science Lab 10
**Embryology**  
HASPI MS Medical Life Science Lab 10c

**Introduction**

In his book, *On the Origin of Species*, Charles Darwin offered several pieces of evidence that supported his theory of evolution. One of the things Darwin discussed was the striking similarity amongst the embryos, or unborn offspring, of complex animals such as humans, chickens, frogs, reptiles, and fish.

When comparing the embryos of different species, similarities can be seen in the early stages of development. Fish and human embryos, for example, both have gill slits, a two-chambered heart, and a tail with muscles to move it. Later on, as the embryos grow and develop, they become less and less similar. The gill slits and tail of a fish eventually develop into important structures necessary for survival in aquatic environments while the gill slits and tail of the human embryo simply disappear.

Darwin wrote that this uniformity observed in embryo development is evidence for evolution. Humans, along with many other organisms, pass through a number of embryonic stages of development that was inherited from common ancestors that started out the same, gradually evolved different traits, but had the same basic mechanisms of early development. The farther into development that two different species maintain similarities, the more closely related they are evolutionarily.

In this activity you and your partners will complete the PBS NOVA activity, “Timing Is Everything,” in which you will be tasked with putting the developmental stages of a few different animals in the correct order.

**Materials**

*Timing Is Everything* student handout  
Scissors  
Tape or glue
### Task

1. Obtain the **Timing Is Everything student handout** sheet from your teacher.  

2. Using a pair of scissors, cut out the squares with illustrations of embryos.

3. Correctly match the embryos of the fish, chick, pig, calf, and human. Place them in order from earliest to latest stages of development.

   Tape or glue each illustration in the table below.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Fish</th>
<th>Chick</th>
<th>Pig</th>
<th>Calf</th>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Stage 3</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Analysis Questions

1. What similarities do the embryos have during development?
2. What differences do the embryos have during development?
3. What trends, if any, do you see as the embryos develop from Stage 1 to Stage 3?
4. Which 2 out of the 5 animals in this activity are the most closely related on the evolutionary tree? Justify your answer.
Evolutionary Relationships
HASPI MS Medical Life Science Lab 10
MS-LS4-1, MS-LS4-2, MS-LS4-3
Connections & Applications

Your instructor may assign or allow you to choose any of the following activities. As per NGSS/CCSS, these extensions allow students to explore outside activities recommended by the standards.

1. The influenza virus is one of the most well-known pathogens and is found in many different mammals besides humans. Every year, the influenza virus infects millions around the world, costing the health care industry billions of dollars and claims thousands of lives. One of the main reasons why the virus has always been such a threat to human welfare is because of its rapid rate of mutation.

Conduct a research project to gain a better understanding of the influenza virus. Create a research paper, multimedia presentation, or visual display to summarize your findings. Be sure to include, but do not limit your research on, the following information:

• History of the flu, including major epidemics
• Annual statistics
• Mechanisms for mutation
• Different strains of the flu
• How is the flu vaccine formulated?
• Why does the effectiveness of the flu vaccine change year to year?

2. When scientists discover a fossil skull, they compare it to skulls that have already been identified as particular early human species. Access and complete the Mystery Skull Interactive Simulation on the Smithsonian, National Museum of Natural History’s website.

http://humanorigins.si.edu/evidence/human-fossils/mystery-skull-interactive

Identify the 4 mystery skulls and provide a brief description of the clues that led you to your findings.
3. Watch one of the following TED Talks

**Will Our Kids Be a Different Species?**, Juan Enriquez (Futurist)
https://www.ted.com/talks/juan_enriquez_will_our_kids_be_a_different_species

**What Veterinarians Know That Physicians Don’t**, Barbara Natterson-Horowitz (Cardiologist)
https://www.ted.com/talks/barbara_natterson_horowitz_what_veterinarians_know_that_doctors_d on_t

**DNA Clues to Our Inner Neanderthal**, Svante Pääbo (Geneticist)
https://www.ted.com/talks/svante_paeaebo_dna_clues_to_our_inner_neanderthal

**Digging Up Dinosaurs**, Paul Sereno (Paleontologist)
https://www.ted.com/talks/paul_sereno_digs_up_dinosaurs

Write a one to two paragraph response to the article. Be sure to:

- Summarize the main points the author is trying to make in the article
- Share your thoughts about the article.
  - Do you agree/disagree with statements made in the article?
  - Have you experienced real life examples that relate to the ideas discussed in this article?
  - How does this article relate to other things you have read or learned about?
  - What would you like to know more about after reading this article?
- How does the presentation relate to evolution?