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Accelerated Biology
Evolution and Classification

Evidence for Evolution: Anatomy

Evolutionary biologists study how different organisms have evolved over time. There are many different ways that scientists can contribute data for organisms changing over time. One of the ways evolutionary biologists can study this is by comparing the structures of different organisms.

Go to http://evolution.berkeley.edu/evolibrary/article/similarity_hs_01. Complete this module and answer the questions below in order to understand some of the evidence Evolutionary Biologists look at. Note, there are not questions for every page on the module, but the questions are in order.

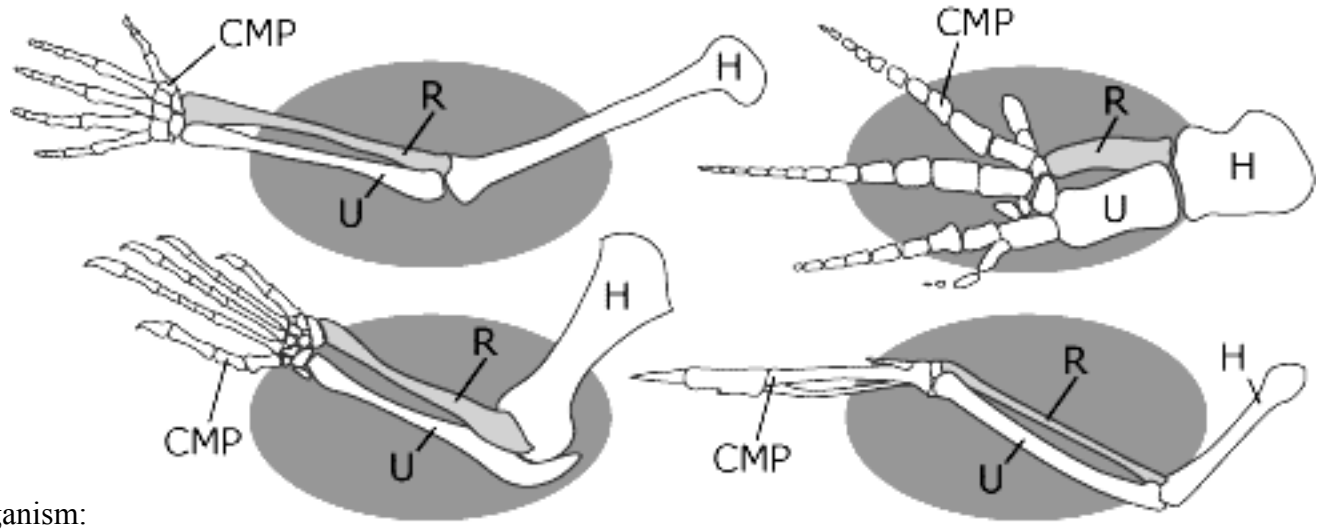
1. What is the difference between a homology and an analogy?

Homologous Structures

2. *Color* in the picture below to show the bones that homologous between these different species.

3. *Label* the organism that each limb comes from.

Organism: _____ Organism: _____



Organism: _____ Organism: _____

H = Humerus U = Ulna

R = Radius CMP = Carpals, Metacarpals and Phalanges

4. Explain, in a few sentences, why these structures might provide evidence for evolution.

Analogous Structures

5. Give an example of an analogous structure.

6. Do analogous structures comes from a common ancestor?

7. How do analogous structures evolve?

8. Summarize how Evolutionary Biologists determine whether a structure is a homology or an analogy.

9. Is a Panda's thumb homologous or analogous to a human's thumb? Why? (Open a new window and go to http://evolution.berkeley.edu/evolibrary/article/side_0_0/analogy_06)

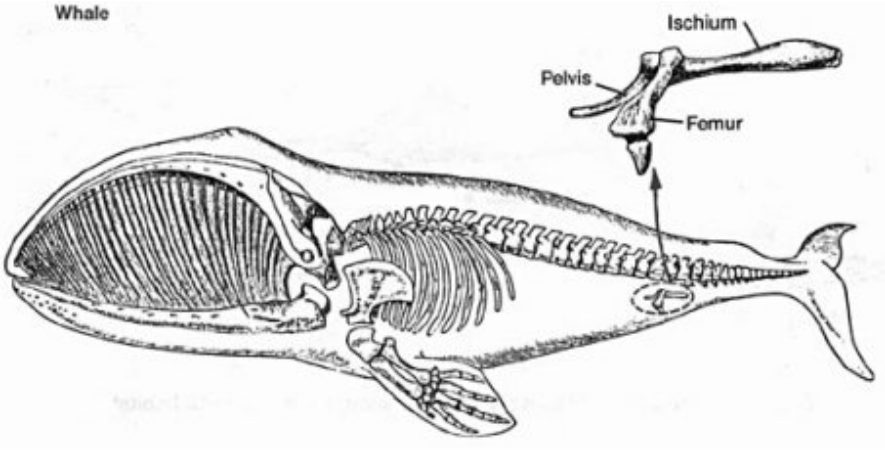
10. Are the wings of the of sugar gliders and flying squirrels homologous or analogous structures? Why?

Vestigial Structures

Look at the following structures. All of these organisms have vestigial structures. After looking at these pictures, define a vestigial structure:

Blind mole rat has eyes, which are covered by layer of skin

Ostriches have wings, yet they can't fly



Leg bones can be found in a whale

11. Define vestigial structures.

12. Why do you think organisms have these structures? (HINT: think about what we're studying)

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Evidence for Evolution: Fossil Record

Directions: This activity will take you through a series of movie clips, pictures, and interactive problems. Follow the directions and answer any questions you encounter along the way. Get a computer and log on.

Step 1: Using your computer, access the video on the site listed below and answer the questions below.

http://www.pbs.org/wgbh/evolution/library/04/3/l_043_01.html

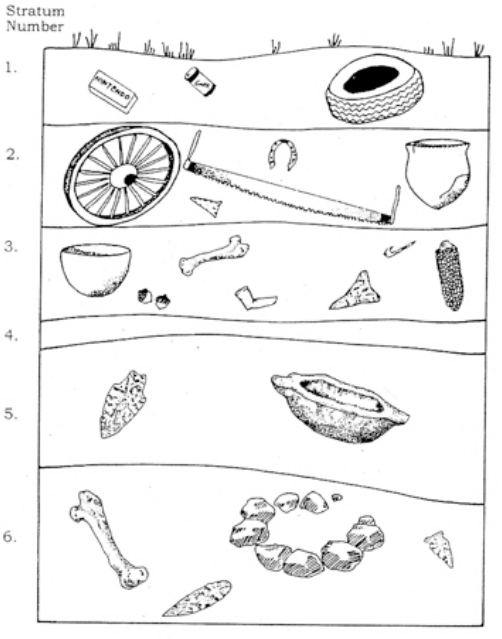
1. Do all organisms that die turn into fossils?

2. What conditions are needed for a fossil to form?

3. What are some things that might cause an organism not to turn into a fossil?

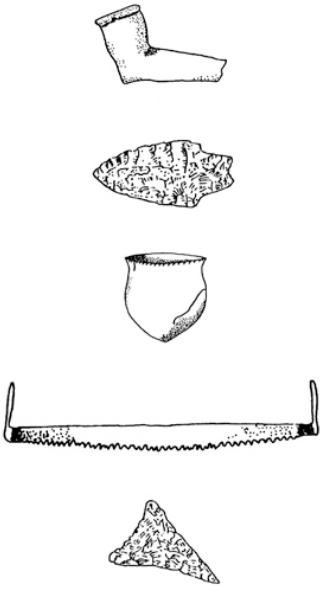
Step 2: Assigning a date to a fossil can be a tricky task. There are two main ways that scientists can date a fossil. The first is **Indirect Dating**. This involves using fossils and the layers of rock they were discovered in to determine the relative date of the fossil. The other method is **Direct Dating**. This involves using a sample of the fossil and the composition of its atoms to determine the age of the fossil. The Direct Dating method gives a much more precise age compared to the Indirect Dating method.

Indirect Dating
To the right is a recently discovered part of Yellowstone National Park. It has exposed layers of sedimentary rock. As you can see, there are many artifacts located within each layer. Even though they are not all fossils, you can use this as a comparison to how scientists would date fossils in this manner.



1. If these strata were layers in the earth's surface, what inferences might you make about the relationship between the depth of the layer and the amount of time that has passed?

2. The following artifacts were found in a dig site 10 miles from the one on the previous page. Draw a segment of sedimentary layers and place the artifacts into the correct order of age. You will need to refer back to the previous illustration to do this.



3. Does this method provide a precise measurement of age for artifacts and fossils? Why not?

Watch the following video on Plate Tectonics and Fossils.
http://www.youtube.com/watch?v=xV36ptFUspg

1. Explain how Pangea and Continental Drift theory provide evidence for changes in the earth. Think about how the movement and separation of continents affected the organisms living on land in earth's distant past.

Direct Dating

Direct Dating uses the matter that the fossil is made up of to calculate the actual age of the fossil. Certain atoms are considered unstable and will break down over time. For example Carbon-14 (isotope of carbon) will break down into Nitrogen over a long period of time. We normally have Carbon-12 in our bodies and it is not unstable, but all living things have a small amount of Carbon-14. Scientists can date the fossil by looking at how much of the total Carbon-14 has broken down. Scientists have found that it takes half of Carbon-14 to break down in 5730 years. So we can calculate how much has broken down and then determine the age of the fossil when the organism died.

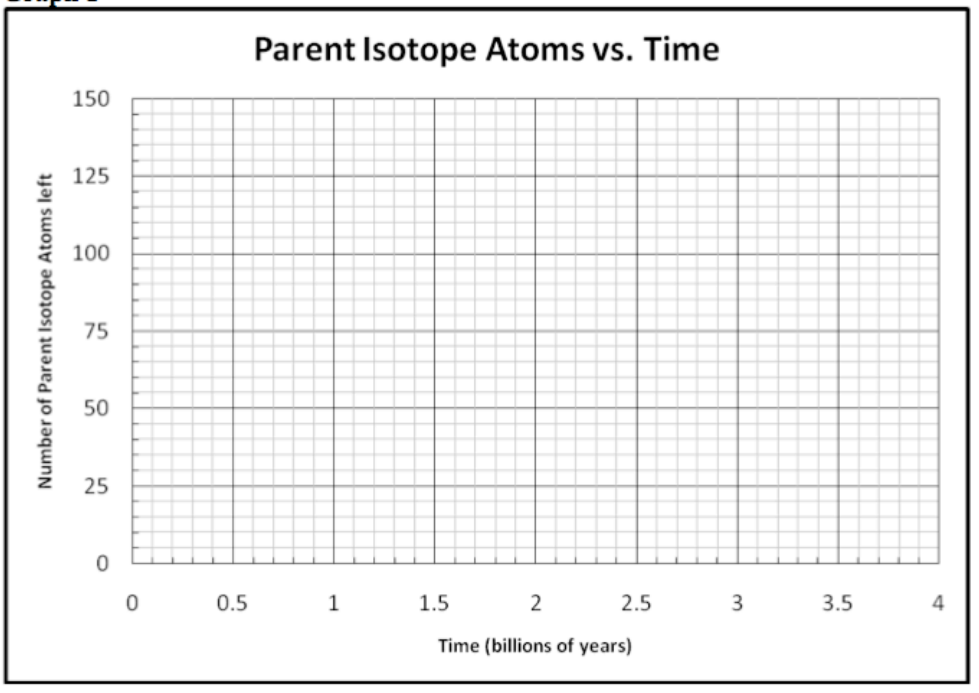
Understanding Half-Lives and Radioactive Decay

Instructions: Fill out the table using what you know about half-lives. For the last row use the half-life of ^{235}U: ***$t_{1/2}$ =704 million years.***

$t_{½}$ Half lives	0	1	2	3	4	5
P: Number of parent isotopes	96					
Percentage of P_0 Remaining	100%					
D: Number of daughter isotopes	0					
Total Atoms: P+D	96					
D/P Ratio	0					
Time since formation (millions of yrs)	0					

Graph the above data in the table below. The axes are already filled out you ☺!

Graph 1



1. If the fossil only had 25 atoms of the isotope left, what would be the age of the fossil?

2. If the age of the fossil was determined to be 2 billion years old, how much of the isotopes would be left?

3. What is the difference between the Indirect Dating method and the Direct Dating method?

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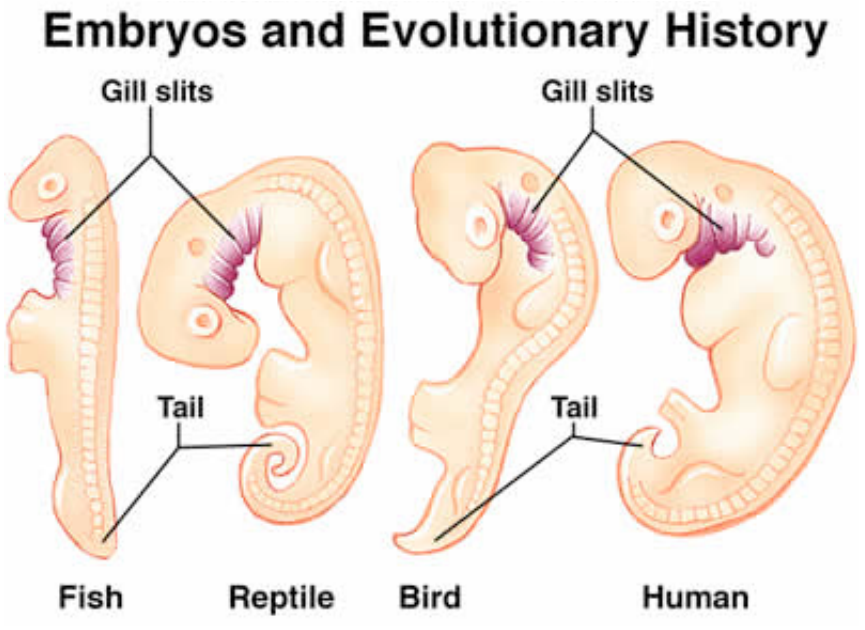
Evidence for Evolution: Embryology and DNA

Part 1

Directions: An embryo is a stage of development for organisms. Examine the picture of four sets of embryos from different organisms.



1. Describe three similarities of the embryo structures during early developmental stages of different organisms?

   a.

   b.

   c.

2. Relate this picture to the idea that organisms evolved from a common ancestor.

Part 2

Deoxyribonucleic acid (DNA) codes for proteins that your body needs to live. One of those proteins is the hemoglobin protein that is found in your blood. This protein carries oxygen and carbon dioxide as they circulate in your bloodstream. Other animals' blood also contains hemoglobin, but not all of these proteins are identical. The differences between the hemoglobin of humans and other animals are caused by differences in the DNA that codes for them.

The scientists who study biological molecules such as DNA or proteins are known as *molecular biologists*. DNA and proteins are ideal molecules to study when looking for evolutionary relationships between organisms because changes in their structure (mutations in DNA) pile up through time. The more closely two organisms are related, the less time that has elapsed since they shared a common ancestor. Less time means a fewer number of differences (mutations) between each organism. If two organisms are very distantly related, we would expect a great number of differences in their DNA since more time has passed to allow for more mutations to occur. With the advancement of DNA technology, scientists have been able to compare these 'genetic documents" that relates an organism's evolutionary history.

In the following activity, you will use this knowledge of DNA and the evidence it can provide to determine the evolutionary relationships between humans and some of our primate relatives. (Note that you could do find the same evolutionary relationships by comparing the proteins of different organisms)

Procedure

1. Observe the segments of the hemoglobin gene for the four primates on the next page.
2. Circle/highlight all the letters in the chimpanzee, gorilla, and orangutan genes that are *different* from the human gene. Be sure to go through all three segments (which are all one piece of DNA)
3. Total the differences in the data table below.
4. Calculate the % similarity between the ape and the human genes.
5. Answer the analysis questions.

Table 1: DNA variation in Chimpanzees, Gorillas, and Orangutans compared to Humans

Differences in Hemoglobin Gene	# Differences	# Similarities (180 – # Differences)	% Similarity (# Similarities/180) x 100
Chimpanzee			
Gorilla			
Orangutan			

Analysis Questions: Answer using complete thoughts and complete sentences. Write neatly using PEN or type your answers on a separate piece of paper.

1. Explain, citing evidence, which of the apes is most closely related to humans.

2. Explain, citing evidence, which of the apes is most *distantly* related to humans.

3. What is the relationship between time and the number of mutations that are present in the DNA of an organism?

4. Does the data in Table 2 (below) support your conclusions made using Table 1 data? Explain why or why not.

Table 2: Time of Last Common Ancestor between Primate and Humans

Primate	Millions of Years Since Last Human Common Ancestor
Chimpanzee	7
Gorilla	10
Orangutan	12
Gibbon	15

5. If a segment of gibbon DNA were sampled, what do you believe the % similarity to humans might be? (Give an approximation)

6. Describe how molecular biologists can give evidence for evolution.

Developmental Biologist Copymaster: DNA Comparison (continued)

Comparisons between portions of the genetic code for β hemoglobin in four primates

Note: spaces where the symbol – occurs in place of a letter indicate a gap and should be counted as a mismatch.

chimpanzee	TAT–AAATGTGTTTCCTGCATATAGTCAAAGTTGCCACTTCTTTTT––TCTTCATATCATC
gorilla	TAT–AAATGTGTTTCCTGCATACAGTCAAAGTTGCCACTTCTTTTT––TCTTCATATCATC
human	TAT–AAATGTGTTTCCTGCATATAGTCAAAGTTGCCACTTCTTTTT––TCTTCATATCATC
orangutan	TCTCAAAAAAAAAAAAAAAAAAGATTCAAAAGATTCACTTGTTTAGGCCTTAGCGGGCTT

chimpanzee	TTTAACT–CTTTGAAATTTAGAGTCTCCTTGAAATACACATGGGGGTGATTTCCTAAACT
gorilla	TTTAACT–CTTTGAAATTTAGAGTATCCTTGAAATACACATGGGGGTGATTTCCTAAACT
human	TTTAACT–CTTTGAAATTTAGAGTCTCCTTGAAATACACATGGGGGTGATTTCCTAAACT
orangutan	CTCATCCACCCTTAGATTGAGAGAAGTCACTTATTAT–TATGTGAGTAACTGGAAGATAC

chimpanzee	GGTGGAAGTGTGCCCTGTCTATTCCTGAAATT–––GCTTGTTTGAGACGCGTGAGACG–T
gorilla	GGTGCAAGTGCGCCCTGTCTATTCCTGAAATT–––GCTCGTTTGAGACGCATGAGACG–T
human	GGTGGAAGTGTGCCCTGTCTATTCCTGAAATT–––GCTTGTTTGAGACGCATGAGACG–T
orangutan	AGCCGCCTAACACTTTGAGCAGATATAAGCTTTACACAAGATTATGAAGGCTGAAAGGAT

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Evidence for Evolution: Molecular Evidence

Concepts such as evolution and natural selection have been applied to many areas of biology. One new area these concepts are being applied is protein molecules. Molecular Biologists compare the molecules of different organisms to look for evidence of evolution. In this activity you will compare the various structures of a protein in several organisms.

Recently, many studies have been made of certain protein molecules, such as Cytochrome c. This protein plays a role in respiration and is found in organisms ranging from yeasts to human beings. When human Cytochrome c is compared to that of other organisms, similarities and differences are found. When the amino acids are compared, those sequences that are similar are called homologies. Those that are different are called amino acid "substitutions."

Table 1 shows the corresponding parts of Cytochrome c amino acid sequences of nine vertebrates. The numbers along the side of the table refer to the position of these sequences in the chain. The letters symbolize the specific amino acids in the chain.

TABLE 1: Cytochrome c amino acid sequence

	Horse	Chicken	Tuna	Frog	Human	Shark	Turtle	Monkey	Rabbit
42	gln	gln	gln	gln	gln	gln	gln	gln	gln
43	ala	ala	ala	ala	ala	ala	ala	ala	ala
44	pro	glu	glu	ala	pro	glu	glu	pro	tyr
46	phe	phe	tyr	phe	tyr	phe	phe	tyr	pro
47	thr	ser	ser	ser	ser	ser	ser	ser	ser
49	thr	thr	thr	thr	thr	thr	thr	thr	thr
50	asp	asp	asp	asp	ala	asp	glu	ala	asp
53	lys	lys	lys	lys	lys	lys	lys	lys	lys
54	asn	asn	ser	asn	asn	asn	asn	asn	asn
55	lys	lys	lys	lys	lys	lys	lys	lys	lys
56	gly	gly	gly	gly	gly	gly	gly	gly	gly
57	ile	ile	ile	ile	ile	ile	ile	ile	ile
58	thr	thr	---	thr	ile	thr	thr	ile	thr
60	lys	gly	asn	gly	gly	gln	gly	gly	gly
61	glu	glu	asn	glu	glu	gln	glu	glu	glu
62	glu	asp	asp	asp	asp	glu	glu	asp	asp
63	thr	thr	thr	thr	thr	thr	thr	thr	thr
64	leu	leu	leu	leu	leu	leu	leu	leu	leu
65	met	met	met	met	met	arg	met	met	met
66	glu	glu	glu	glu	glu	ile	glu	glu	glu
100	lys	asp	ser	ser	lys	lys	asp	lys	lys
101	ala	ala	ala	ala	ala	ala	thr	ala	ala
102	thr	thr	thr	gly	thr	ala	thr	ala	thr
103	asn	ser	ser	ser	asn	ala	ser	asn	asn
104	glu	lys	---	lys	glu	ser	lys	glu	glu
% subst.									

Evolutionary Relationships

1. Compare each organism's Cytochrome to human Cytochrome. Highlight the amino acids that differ from the human sequence.
2. To calculate the percentage of difference for each Cytochrome from human Cytochrome, divide the number of substitutions for each organism by the total number of amino acids in the sequence (25). Record in the last row of Table 1.
3. List the nine vertebrate sequences in descending order according to their degree of evolutionary closeness to humans in Table 2. Closest to humans at the top.

TABLE 2: Evolutionary Relationships

1	Human
2	
3	
4	
5	
6	
7	
8	
9	

Molecular Clock

Other proteins, such as hemoglobin, can also be used to establish degrees of evolutionary closeness among organisms. Scientists can go one step further with Cytochrome c. It can actually be used as a sort of molecular clock, keeping evolutionary time. Because Cytochrome is found in the mitochondria, and mitochondria are inherited only from the mother or egg cell, there is no sexual variation in its sequence from generation to generation. Instead, the only variation that occurs is a direct result of mutation.

When species, or phyla, diverge, they begin to have mutations different from one another and the "clock" starts ticking. To get an idea of how the clock is calculated follow these directions.

4. Use the percentage of difference from Table 1 to calculate the average percentage of change of Cytochrome c for each million years of Earth history. To do this, divide the percentage of change for each organism , frog (amphibian), turtle (reptile), etc., by the number of million years from that organism's point of divergence from Table 3. Then average the eight quotients together. Record this data in Table 4.This number is the average amount of change in Cytochrome c that has occurred over each 1 million years of the last half billion years.

TABLE 3 – Approximate Dates of Convergance

Vertebrates	Diverged (MYA)
Monkeys	35
Mammals	225
Reptiles	320
Fish	425
Amphibians	405
Modern Birds	135

Percentages of Change per 1 million years

Average percentage = _____

5. What does the average percentage show?

6. Could this same technique be used on the molecule DNA? Explain.

7. The more alike two organisms DNA, the . . .

8. What evidence do biological molecules provide for change over time?