Name _____
Date _____ Period __

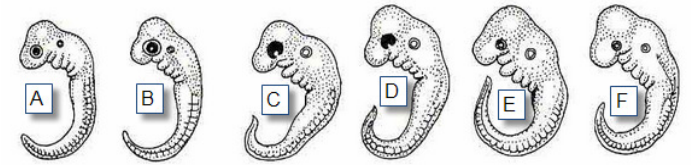
Evidence for Change

Background – Much evidence has been found to indicate that living things have evolved or changed gradually during their natural history. The study of fossils as well as work in embryology, biochemistry, and comparative anatomy provides evidence for evolution.

Objective – In this lab you will learn about homologous, analogous, and vestigial structures and their significance in evolution theory.

Procedures and Observations – Part I – Embryology

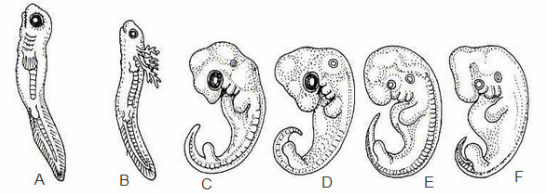
1) Organisms that are closely related may also have physical similarities before they are even born! Take a look at the six different embryos below:



2) The 6 embryos above are a chicken, a fish, a human, a rabbit, a salamander, and a tortoise.

   Can you tell which embryo is which based solely on the picture in #1? Why or why not?

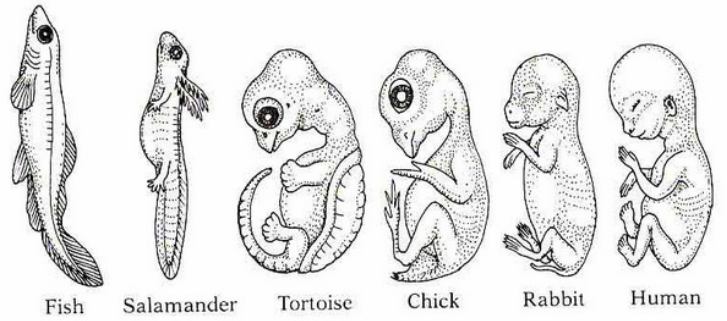
3) These are older, more developed embryos from the same organisms.



4) Hypothesize which embryo is from each of the following organisms by matching the letter of the embryo with the species.

Species	Embryo (letter)	Species	Embryo (letter)
Human		Tortoise	
Chicken		Salamander	
Rabbit		Fish	

5) These are embryos at their most advanced stage, shortly before birth.



Analysis – Describe how the embryos changed from their early to late stages.

1) Look again at the six embryos in their earliest stages. Describe the patterns you see. What physical similarities exist between each of the embryos? (name at least 3)

2) The human embryo was letter F. Which organism's embryo(s) became different from the human embryo the earliest in development?

3) What does this say about the relatedness of this(ese) organism(s) and humans?

4) Which organism's embryo(s) where the same as the human embryo the longest in development?

5) What does this say about the relatedness of this organism and humans?

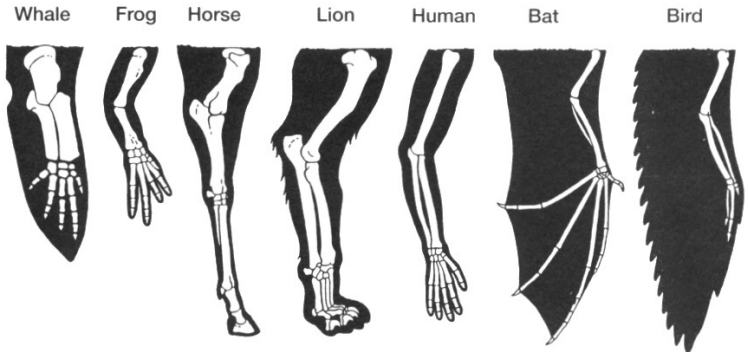
Summary: Some apparently unrelated animals share similar structures and appearance until surprisingly far in their development as embryos. This also provides evidence for a recent common ancestor.

Procedures and Observations – Part II – Homologous structures

Material needed – colored pencils

1) Carefully examine the drawings of the bones shown in the figure below and look for similarities among the various animals.
2) Color each part of the human arm a different color. (All bones of the wrist should be a single color, the bone groups of the hand should be a different color.)
3) Color the corresponding bone in each of the other animals the same color as the human bone.
4) Relate the differences you see in form to the difference in function for the following animals:

Animal	Function
Whale	
Frog	
Horse	
Lion	
Human	
Bat	
Bird	



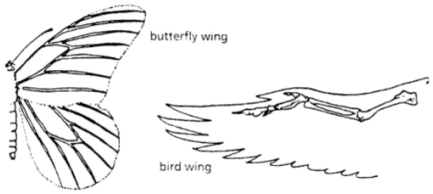
5) Are the bones arranged in a similar way in each animal? _____

Summary: The structures on the previous page are formed in similar ways during embryonic development and share like arrangements. This also provides evidence for a recent common ancestor (evolution). However, these structures have slightly different form and function. They are called *homologous* structures.

Procedures and Observations – Part III – Analogous Structures

1) Examine the butterfly wing and bird wing in the figure to the right.
2) What function do they each share?

_____



3) How do these wings differ in structure? _____
4) Do birds and insects share any structural similarities that would suggest they have a recent common ancestor? Explain. _____

_____

_____

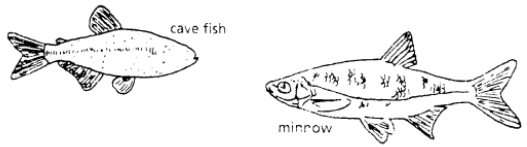
Summary: Some apparently unrelated animals have structures or organs with similar functions, yet they are very different in form. These structures are called *analogous structures*.

Procedures and Observations – Part IV – Vestigial Structures

Gradual changes occur through time that in some cases reduce or remove the function of a body structures or organs. A penguins' wing (they don't fly), leg bones of snakes (they don't walk), and human tail bones (we don't have tails) are examples of this phenomenon.

1) What is the most obvious difference between the cave fish and minnow shown below?

_____



2) Why did the cave fish evolve without eyesight? _____

_____

3) Does the general appearance of the cave fish and minnow suggest they have a recent common ancestor? Explain.

_____

_____

4) Human vestigial structures have been well documented. Read the list of human vestigial structures in the table below and suggest a possible function for each as well as an explanation for why it became vestigial.

Structure	Probable Function	Why did it become vestigial?
Coccyx (tail bones)	Used for balance when walking on all fours. Used to swing from tree to tree.	We walk upright now and so our center of gravity has changed so that we no longer need a tail for balance. We don't live in trees.
Appendix		

Structure	Probable Function	Why did it become vestigial?
Muscles that move the ear		
Little toe		
Wisdom teeth		

Analysis:

1) Explain why homologous structures in Part 2 are evidence of evolutionary relationships.

2) Explain the evolutionary relationship between the fin of fish and the flipper of a whale.

3) List two structures (not from the table on this page) that you think are vestigial and explain why.

4) Of *homologous, analogous, and vestigial* structures, which provide the best evidence for evolution from a recent common ancestor? Explain.

Vestigial Structures Summary: Organs or structures that have lost their function or become reduced in size (to make the organism more efficient) are called *vestigial* structures.

Procedures and Observations – Part V – Biochemical Evidence

Studying biochemical similarities, such as amino acid sequences of proteins or nucleotide sequences of DNA, provide significant evidence to support the theory of evolution. Though mold, pine trees, mushrooms, alligators, and humans appear to have little in common physically, a study of their proteins reveals certain similarities. Biologists have perfected techniques to determine amino acid sequence of proteins. By comparing the sequences of homologous proteins we can see evolutionary relationships that might otherwise go unnoticed. The greater the similarity between the amino acid sequences of proteins in two different organisms, the closer the relationship. Conversely, the greater the difference, the more distant the relationship is.

Objective: Determine how amino acid sequences of a protein provide evidence for relatedness between organisms and therefore insights into the process evolution.

1) Examine the table below. It compares corresponding portions of hemoglobin molecules in humans and five other vertebrate animals. Hemoglobin, a protein composed of 4 long chains of amino acids, is the oxygen-carrying molecule in red blood cells. Only a portion of the hemoglobin molecule is shown. The number in the table indicates the position of particular amino acids in the chain.

Table 1 – amino acid sequence in hemoglobin

Animal	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101
Human	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Chimpanzee	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Gorilla	THR	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Monkey	GLN	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Horse	ALA	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU
Kangaroo	LYS	LEU	SER	GLU	LEU	HIS	CYS	ASP	LYS	LEU	HIS	VAL	ASP	PRO	GLU

Animal	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
Human	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Chimpanzee	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Gorilla	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Monkey	ASN	PHE	LYS	LEU	LEU	GLY	ASN	VAL	LEU	VAL	CYS	VAL	LEU	ALA	HIS
Horse	ASN	PHE	ARG	LEU	LEU	GLY	ASN	VAL	LEU	ALA	LEU	VAL	VAL	ALA	ARG
Kangaroo	ASN	PHE	LYS	LEU	LEU	GLY	ASN	ILE	ILE	VAL	ILE	CYS	LEU	ALA	GLU

2) Fill in the chart below by writing in the position and amino acid abbreviation that is different from that of human hemoglobin. Always compare the amino acid sequence of each animal to that of the human. (Note: the first two animals have been done for you.)

Animal	Position and Amino Acid Differences Compared to Human							Total # of differences
Chimp	None							0
Gorilla	104-LYS							1
Monkey								
Horse								
Kangaroo								

3) On the basis of hemoglobin similarity, what organisms appear to be most closely related to humans? Explain your answer.

4) Among the organisms that you compared, which appears to be least closely related to humans? Explain your answer.

5) Another commonly studied protein is cytochrome c. This protein, consisting of 104 amino acids, is located in the mitochondria of cells where it functions as a respiratory enzyme. Examine the table to the right. It shows amino acid differences between humans and a number of other organisms.

Cytochrome c—Comparison Table	
Species Pairing	# of Differences
Human-chimpanzee	0
Human-fruit fly	29
Human-horse	12
Human-pigeon	12
Human-rattlesnake	14
Human-red bread mold	48
Human-rhesus monkey	1
Human-screwworm fly	27
Human-snapping turtle	15
Human-tuna	21
Human-wheat	43

6) Which organisms seem to be most related to humans?
_____

7) Which organisms appear least closely related to humans? _____

8) Check the pair of organisms that appear to be most closely related to each other and explain.
_____ snapping turtle and tuna
_____ snapping turtle and rattlesnake
_____ snapping turtle and pigeon

9) The table to the right uses a fruit fly as a standard in comparing amino acid differences among several organisms based on cytochrome c.

Species Pairing	# of Differences
Fruit fly-dogfish shark	26
Fruit fly-pigeon	25
Fruit fly-screwworm fly	2
Fruit fly-silkworm fly	15
Fruit fly-hornworm moth	14
Fruit fly-wheat	47

10) Agree or disagree with the following statement: "Fruit flies appear to be more closely related to silkworm flies than to screwworm flies." Give reasons to support your answer.

11) Name the pair of organisms that appears to be equally related (have the same number of differences) to humans on the basis of cytochrome c similarity. Note: they numbers are the same, but not necessary close to the human sequence.

_____ and _____

12) Is it possible that the organisms in question #11 could be equally related to humans but not equally related to each other? Explain.

13) Agree or disagree with the following statement: "Fruit flies and humans have about the same evolutionary relationship to wheat." Give reasons to support your answer.

Critical Thinking Application:

1) There is a difference of only one amino acid in one chain of the hemoglobin protein of humans compared to gorillas. What might have caused this difference?

2) If the amino acid sequences in the proteins of two organisms are similar, why will their DNA also be similar? (Hint: think of the Central Dogma of Biology)

3) Many biologists speculate that the number of differences between the proteins of different species indicates how long ago the species diverged from a common ancestor. Why do these biologists think that humans, chimpanzees, and gorillas diverged from a common ancestor only a few million years ago (a relatively short time)?

4) Other proteins (besides hemoglobin and cytochrome c) can be used to establish evolutionary relatedness between organisms. Would you expect to find about the same number of differences in the amino acid sequences when comparing organisms? Explain your answer.

Important question!

Example: If you kept examining the proteins of a chimpanzee and a human, would you expect to keep seeing no differences in their proteins. Why or why not? (Give specific examples of proteins/traits that would be different or similar to humans to justify your point of view.)