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Species Diversity and Phylogeny

Content Standards

National C: Life Science

Biological Evolution

- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.
- Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.
- The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities, which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

California Ecology 6. Stability in an ecosystem is a balance between competing effects.

a. *Students know* biodiversity is the sum total of different kinds of organisms.

California Evolution 8: Evolution is the result of genetic changes that occur in constantly changing environments.

e. *Students know* how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.

Prerequisites

Knowledge:	**Skills:**
Geologic Principle of Superposition	Microscope Use

Materials

1. Microscope
2. Protozoa Lab materials (refer to separate lesson)
3. Prepared Slides of the Eukaryotic Kingdoms
4. Computer and Curricular Materials

Schedule

1. Protozoa Lab
2. Prepared Slide Activity
3. Computer Aided Taxonomy Activity
4. Another Way to Look at Them: Cladistics

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Species Diversity: Taxonomy

Background

On a typical trip to the zoo it is possible to see animals that live in trees, fly, crawl on the ground and hop. Some are huge and others very small. They all have a nameplate because the first thing visitors want to know is what they are called. After that they may want to know what they are related to. Did you know that the lesser panda looks more like a raccoon than the giant pandas and the chimpanzee is so closely related to humans that less than 2% of its DNA is different from ours? That is an interesting 2%. To differentiate organisms scientists have developed classification systems.

You may be familiar with the animal kingdom or the plant kingdom. The kingdom is one type of taxonomic unit (taxa if many or taxon when referring to one). Here is the basic classification system modified from Linnaeus.

Domain
Kingdom
Phylum
Class
Order
Family
Genus species

Notice that the last two are on the same line. When giving the scientific name for an organism both its genus and species is used. The genus is capitalized and the species is not, and both are either underlined or italicized.

The vertebrates and invertebrates (animals without backbones) make up two animal subphyla. Some representative Classes for the Kingdom Animalia are:

Vertebrates:	Mammals
	Birds
	Reptiles
	Amphibians
	Fish
Invertebrates:	Arthropods including: Insects, scorpions, and centipedes
	And, many other invertebrates

Here is the classification of humans using this system:

Domain: Eukaryotes
Kingdom: Animalia
Phylum: Chordates (Have a Notochord)
Sub-Phylum: Vertebrata
Class: Mammalia
Order: Primates
Family: Great Apes
Genus species: *Homo sapiens*

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Directions

1. Follow the directions to the Protozoa Lab

2. Observe and draw from prepared slides organisms or parts of organisms from all the different Eukaryotic kingdoms and bacteria.

3. Use the following websites to find the information you need to fill out the Taxonomy Recording Sheet. Leave the fifth column empty for now.

   http://www.ucmp.berkeley.edu/help/taxaform.html
   http://www.ucmp.berkeley.edu/phyla/metazoamm.html
   http://www.ucmp.berkeley.edu/plants/plantaemm.html
   http://www.ucmp.berkeley.edu/chromista/chromista.html
   http://www.ucmp.berkeley.edu/alllife/eukaryotasy.html
   http://www.ucmp.berkeley.edu/fungi/fungi.html
   http://www.ucmp.berkeley.edu/alllife/virus.html
   http://www.ucmp.berkeley.edu/archaea/archaea.html
   http://www.ucmp.berkeley.edu/bacteria/bacteria.html
   http://www.mansfield.ohio-state.edu/~sabedon/biol3008.htm

4. Use the following websites to find the information you need to fill out the Geologic History or Who Lived Then? Worksheet

   Include:
   - Dates for the time periods
   - The organisms that are known from each time period
   - When each Kingdom and major Animal Phylum appears in the fossil record

   http://www.ucmp.berkeley.edu/help/timeform.html
   http://www.paleoportal.org/time_space/time_space.php
   http://pubs.usgs.gov/gip/geotime/contents.html

5. Go back and fill in the fifth column of the Taxonomy Recording Sheet.

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Taxonomy Recording Sheet

Domain	Kingdom	Examples	Distinguishing Characteristics How do you tell them apart?	Appeared In Fossil Record
Virus	**x**		**1.** **2.** **3.**	
Bacteria	**x**		**1.** **2.** **3.**	
Archaea	**x**		**1.** **2.** **3.**	
Eukaryotes	**Chromista**		**1.** **2.** **3.**	
	Protista		**1.** **2.** **3.**	
	Fungi		**1.** **2.** **3.**	
	Plants		**1.** **2.** **3.**	
	Animals (Metazoans)		**1.** **2.** **3.**	

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Geologic History or Who Lived Then? Worksheet

ERA	PERIOD	Who Was There
Cenozoic	Quaternary	
	Tertiary	
Mesozoic	Cretaceous	
	Jurassic	
	Triassic	
Paleozoic	Permian	
	Carboniferous	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Precambrian Time		

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6. The next activity is "Another Way to Look at Them: Cladistics. This activity was modified from the following site and you may go there for more information: http://www.indiana.edu/~ensiweb/lessons/mclad.html

Another Way to Look at Them: Cladistics

Background

There is another system in use that looks at the evolutionary relationships between organisms and differentiates taxa (taxonomic groups – different organisms) using the closest ancestor that they have in common. This system is called Cladistics or phylogenetic systematics.

A Clade is one phylogenetically related group. Clades have anatomical structures in common. That means they have many of the same body parts and probably a similar body plan. Two very different body plans are exhibited by a cow and a sea star. Cows and sea stars are both animals and so they have the basic animal characteristics in common but one is an invertebrate and the other is a vertebrate with a very heavy bony backbone. Taxonomists would say that their common ancestor is very far back in geologic time.

So, lets think about some animals that are more closely related to cows. Ensatina Salamanders are amphibians and they have a backbone and they have four legs in two opposite pairs similar to cows. They lay eggs, though, so they are also different from cows, which are mammals whose eggs develop inside a placenta. They are similar to sea stars in that sea stars lay eggs too. Then there are Emus, which are flightless birds. They still have two sets of appendages and each set is opposite: Two short flappy wings and two very good legs for running. They also have four chambers in their hearts just like mammal hearts and produce eggs. Then to finish off, how about including Blue Whales, the biggest animal to ever roam the earth. They are mammals like cows and they certainly have four sets of appendages, flippers. But they can no longer run around on land, sort of like the Emus that can no longer fly. Whales, like all mammals produce eggs and have four-chambered hearts.

All Animals that Produce Eggs

Sea star
Cow
Emus
Salamander
Blue Whale

To learn to classify organisms we first have to put them into categories.

Start with a very big square that includes all of our animals because they all produce eggs. We will color it purple:

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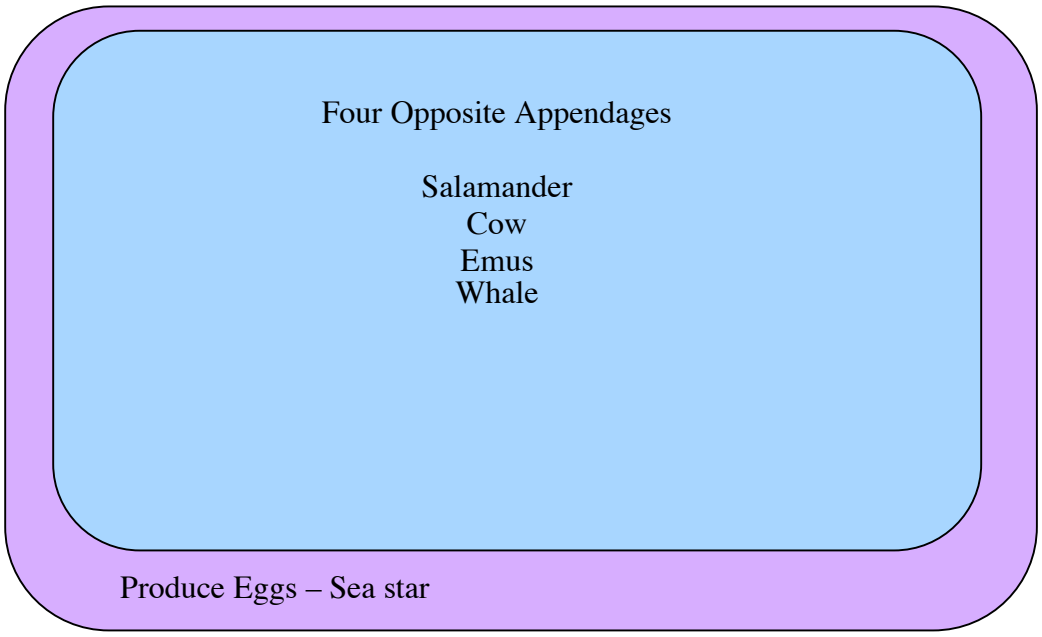
Our Sea star fits only in that category but it will not fit with any of the other characteristics that we used to describe our animals. Here are the characteristics:

4 Opposite Legs	3 Opposite Appendages
Invertebrates	Produce Eggs
4-Chambered Heart	Mammals
Placental Mammals	Mammals with flippers
Birds	Amphibians

- The Salamander produces eggs but it has four opposite appendages.
- The Emus produces eggs, has four opposite appendages but it has a four chambered heart. Salamanders have 3-chambered hearts. Fish have 2-chambered hearts.
- The Cow produces eggs, has four opposite appendages, a four chambered heart but it is a placental mammal.
- The Blue Whale produces eggs, has four opposite appendages, four-chambered heart, is a placental mammal but has appendages modified into flippers.

The idea now is to pick another category that all of the rest of the animals have in common. This category must be the last, which one of our remaining animals has in common with the others.

Salamanders have four opposite appendages but they have 3-chambered hearts and the rest, cow, emus and whale, have 4-chambered hearts



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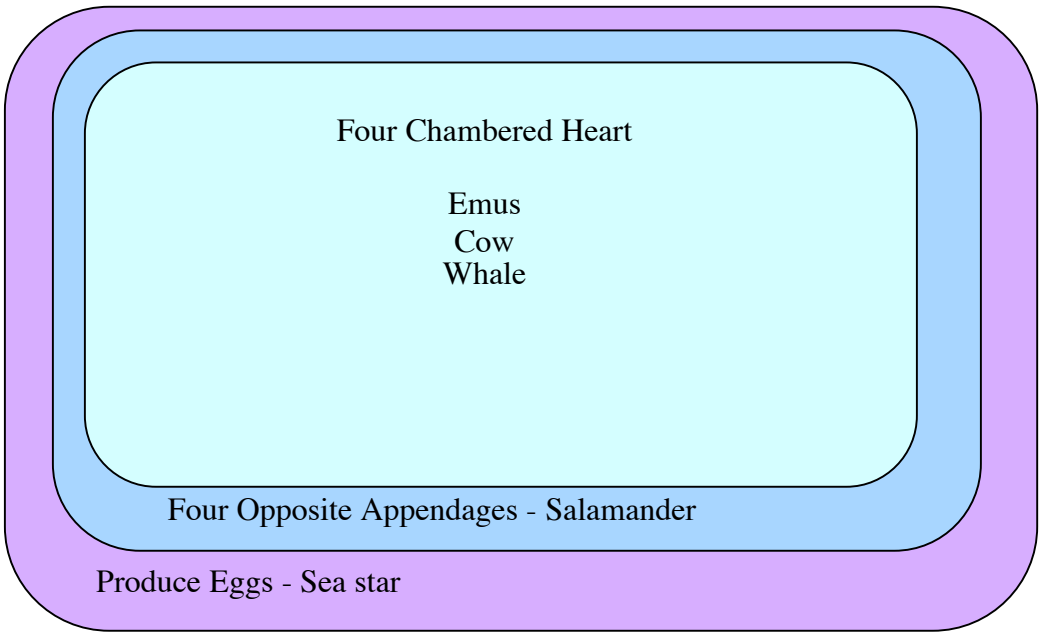
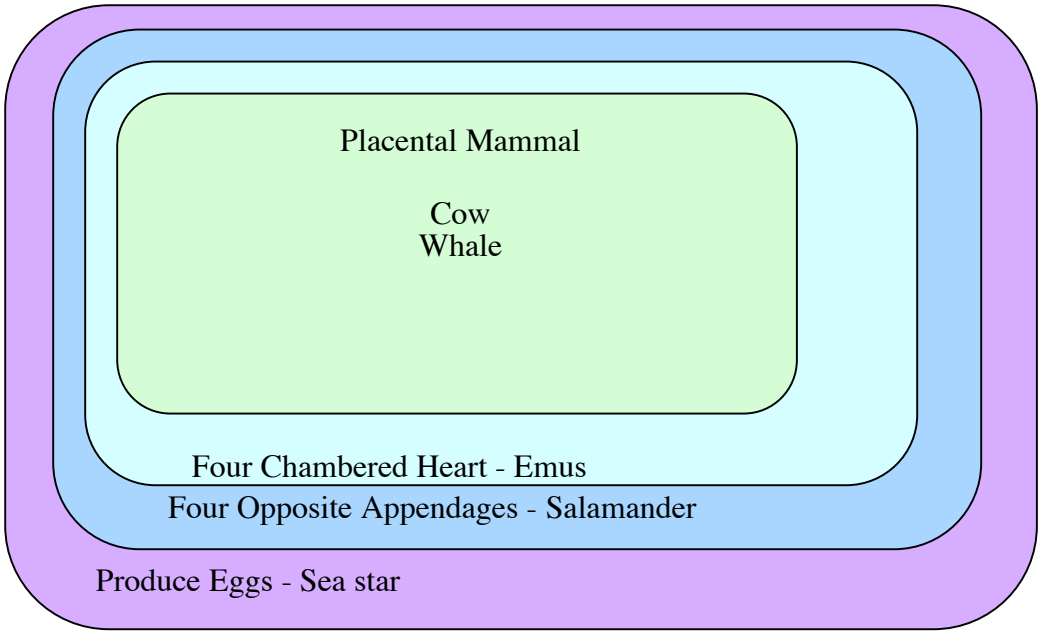
So then the next category would be Four Chambered Hearts.



The Emus has a four-chambered heart but it lays its eggs. It does not have a placenta to mature the growing embryo internally.



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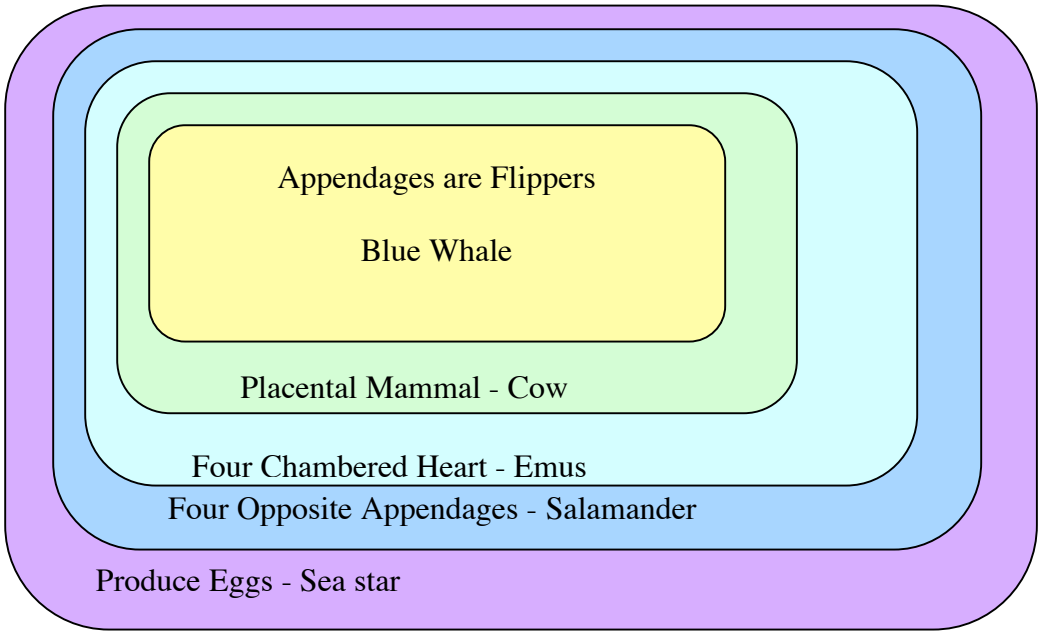
The Cow is a placental mammal but it has legs not flippers.
The Blue Whale is our only organism with all of the characteristics.



You might ask why we choose to make the last characteristic square (yellow) flippers instead of legs and put the cow last and the whale in the green square. That would be a good question. The reason is that taxonomists have concluded from the fossil evidence that whale flippers developed from legs and not the other way around so the legs came first. Those features of the whale are called advanced because they arose more recently out of something else.

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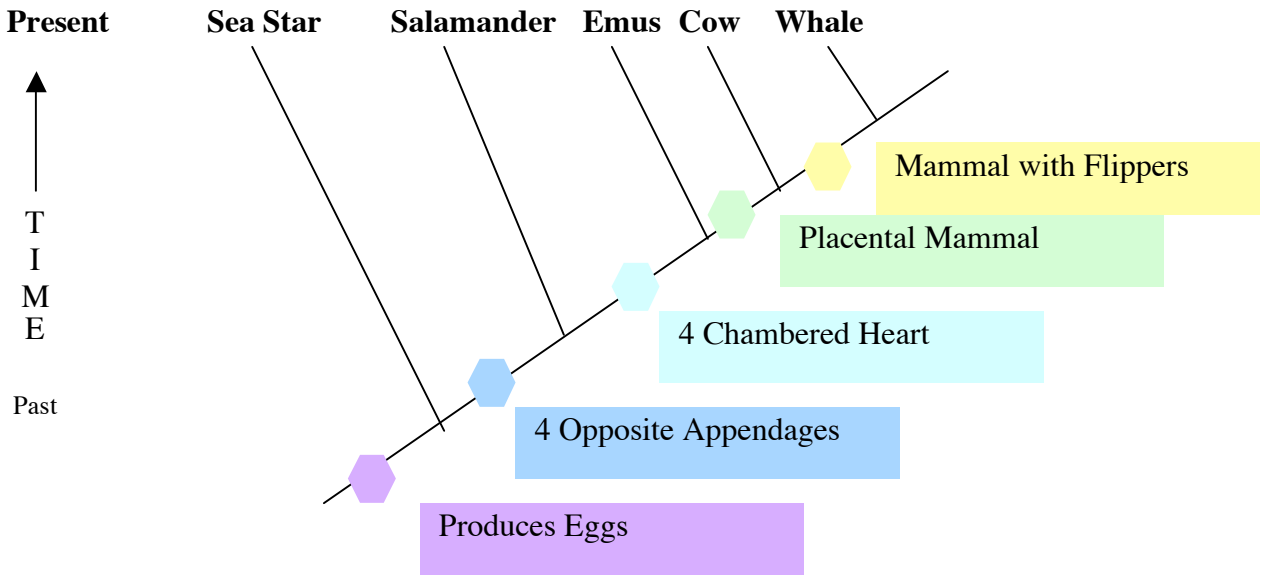
If you draw this diagram of boxes inside of boxes (Venn diagram) like the branches of a tree instead, it looks like this and is called:

A Cladogram



The Blue Whale has all 5 traits.
The Cow has 4.
The Emus has 3
The Salamander has 2.
The Sea Star has only 1.

The Characteristic is understood to have come into being before the particular organism that you happen to be considering evolved so it is labeled on the line leading to the branch not right at the branch.

All of the organisms are still extant (that means they have not gone extinct) so they are living in the same time period, the present, and so they are shown on the same level. That would look different if we were examining fossils from different time periods.

You might say that we stacked the deck by picking organisms that are very different. You are right but there is a natural pattern. It may not be that easy to find the pattern when comparing organisms that are very similar.

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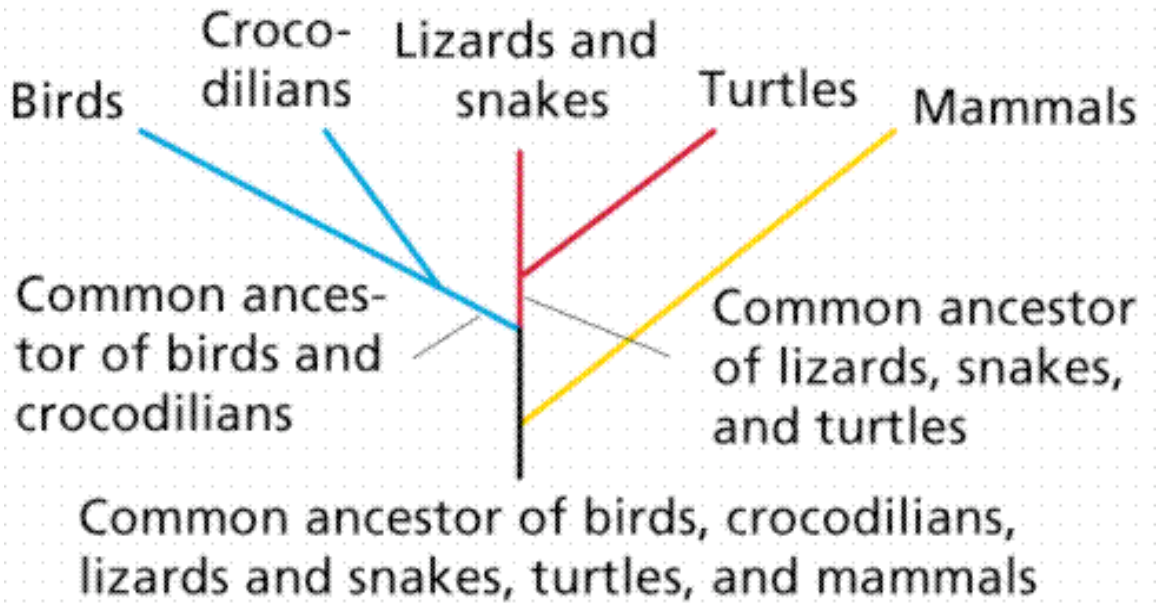
Taxonomists always look very closely at what is called homologous anatomical structures. Homologous structures are parts of the anatomy of organisms that develop from the same cells. After the fertilized egg divides into more cells the cells begin to differentiate into different types of cells and those cells go on to become different distinct areas in the embryo and those areas give rise to different anatomical structures. So the hearts of all animals come from the same area in all embryos. The appendages come from other areas. So all appendages that come from the same area are homologs – comparable structures. Organisms with lots of the same homologous structures are considered to be closely related.

For a more complete discussion of classification systems including Cladistics refer to:

http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookDivers_class.html.

Cladograms can be more complex and drawn in different ways. Here is a typical cladogram (from the above website):



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Practice Developing a Cladogram

Modified from: http://www.indiana.edu/~ensiweb/lessons/mclad.html

First put an x in the squares of the following table where that animal possesses a given trait.

Then add up the number of traits that each organism has.

Some of the less well-known traits have already been provided. The rest of the information can be found in the descriptions above, in the other taxonomy activities. A Lamprey is a primitive fish. A snapping turtle is a reptile. A Kangaroo is a marsupial mammal.

Then create a Venn diagram (boxes inside boxes) to represent the data. If an animal has only one trait it would only be in the largest box. If it has all of the traits it would be in the smallest box.

Then draw and label a Cladogram of the data.

Hint: There is only one animal with all of the traits.

Traits	Kangaroo	Lamprey	Rhesus Monkey	Bullfrog	Human	Snapping Turtle	Tuna
Chordate		**x**					
Vertebral Column							
Paired Legs							
Functionally Four Chambered Heart						**x**	
Mammary Glands							
Placental Mammal							
Short Canine Teeth					**x**		
Total # Of Traits							

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Create your Venn diagram here:

Draw your Cladogram here:

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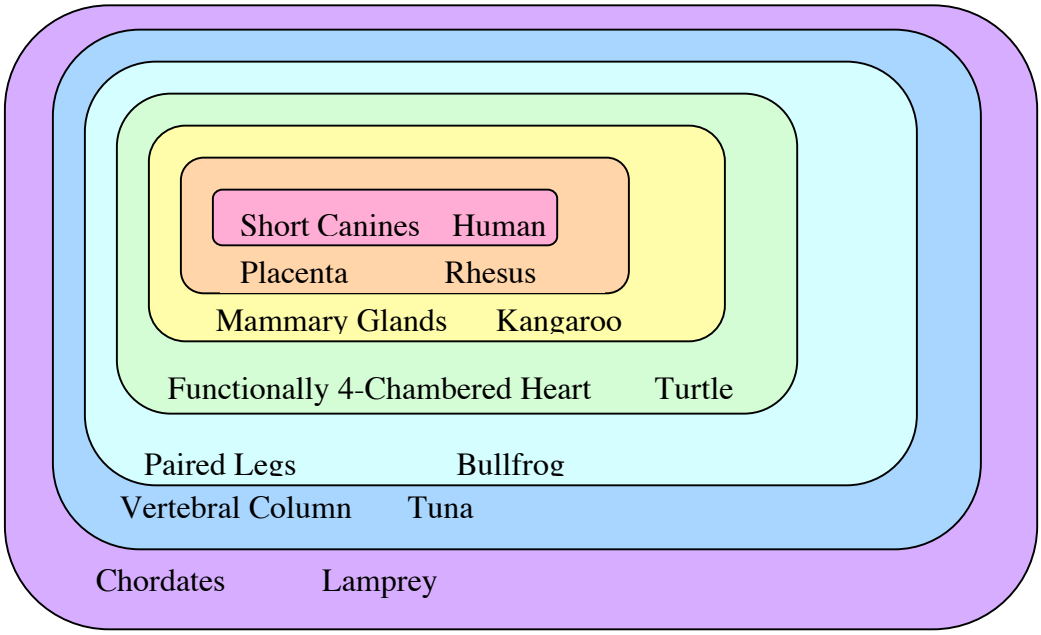
The Answers

Traits	Kangaroo	Lamprey	Rhesus Monkey	Bullfrog	Human	Snapping Turtle	Tuna
Chordates	x	x	x	x	x	x	x
Vertebral Column	x		x	x	x	x	x
Paired Legs	x		x	x	x	x	
Functionally Four Chambered Heart	x		x		x	x	
Mammary Glands	x		x		x		
Placental Mammal			x		x		
Short Canine Teeth					x		
Total # Of Traits	5	1	6	3	7	4	2



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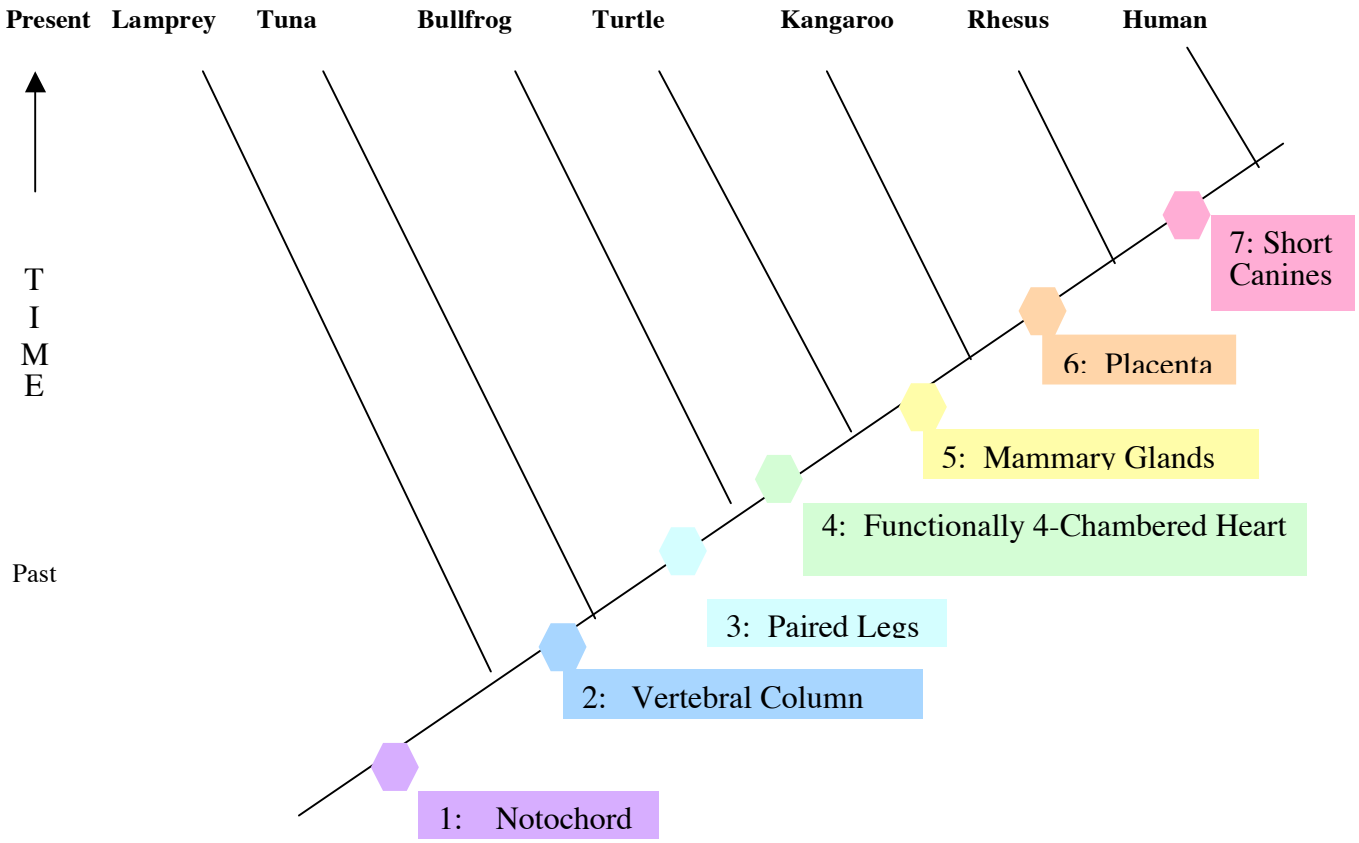
A Cladogram



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Geologic History or Who Lived When? (With Answers)

	PERIODS	Who Was There
Cenozoic	**Quaternary** Began 1.8 mya	**Eukaryotes: Protists; Fungi; Plants; Animals: Reptiles, Birds, Amphibians, Fish, Mammals, Invertebrates, etc. including Homo sapiens Archaea and Bacteria**
	Tertiary 65 mya	**Birds; Mammals; Amphibians; Reptiles; Fish; Insects; Nautilus; Flowers; Ferns; Trees; Bacteria; Algae**
Mesozoic	**Cretaceous** 144 mya	**Dinosaurs and Ammonites going extinct! Birds; Mammals; Amphibians; Reptiles; Fish; Insects; Squid; First Flowers; Ferns; Trees; Bacteria; Algae**
	Jurassic 206 mya	**First Birds; Mammals; Amphibians; Reptiles – Abundant Dinosaurs; Fish; Insects; Ammonites; Ferns; Trees - Conifers; Aquatic Plants; Bacteria and Algae**
	Triassic 248 mya	**Amphibians; Reptiles; First Dinosaur; pterosaurs; Fish; Insects; Ammonites; First Mammals; Ferns; Trees - Conifers; Aquatic Plants; Bacteria and Algae**
Paleozoic	**Permian** 290 mya	**Trilobites Gone! Marine Extinctions! Amphibians; Reptiles; Fish; Insects; Ammonites; Ferns; Trees; First Conifers; Aquatic Plants; Bacteria and Algae**
	Carboniferous 354 mya	**Amphibians; First Reptiles Trilobites; Ammonites; Abundant Insects; Fish; Primitive Trees; Ferns; Aquatic Plants; Bacteria and Algae Amniotic Egg Breakthrough!**
	Devonian 417 mya	**First land Animals with legs – Amphibians and Insects; Trilobites; Fish Rule! Sharks appear; Ammonites; Land Plants; Aquatic Plants; Bacteria and Algae**
	Silurian 443 mya	**First land animals – Centipedes and Scorpions; Trilobites; First Fish with Jaws; First Land Plants; Aquatic Plants; Bacteria and Algae**
	Ordovician 490 mya	**Marine Extinctions! Invertebrates- octopus; Trilobites; First Fish Aquatic Plants; Bacteria and Red and Green Algae**
	Cambrian 543 mya	**First hard skeletons; Marine Invertebrates: Trilobites; Primitive Aquatic Plants; Bacteria and Algae**
Precambrian Time 4,500 mya		**Primitive Aquatic Plants Complex Multicellular organisms including the first animals Bacteria and Algae Eukaryotic Cells Evolve Life Originates**