

Finding Order in Nature

- People have classified the natural world for thousands of years based on traits such as:
 - _____ - “We can eat these plants, but not these.”
 - _____ meaning - “These animals are sacred, these are evil.”
 - _____ - “These animals pull our plows, those we shear for wool.”

Naturalistic Systematics

- Around the 18th century, _____ sought to classify nature in a way that reflected nature, rather than the way humans use nature.
- Of course, there was disagreement about what constituted a “_____” system, or even if a “natural” _____ was necessary.

Linnaeus

- In 1735, Carl von Linnae (“Linnaeus”) published _____ *Naturae*, a new approach to classifying nature that used nested hierarchies. _____ system is grounded in this method.
- 1736: Linnaeus published a system of _____ nomenclature, still in use today.
- 1753: Linnaeus published *Species Plantarum*, describing and _____ known organisms.

Linnaean System

- Three Kingdoms of nature: _____, _____, _____.
- Within each Kingdom, organisms are organized into _____.
- Linnaeus’ system was considered “_____,” based on observable _____ features. However, it was so useful for identifying organisms that most people preferred it over other systems, even though some naturalists disagreed with Linnaeus’ approach - and each other.

2 Kingdom system

- Linnaeus divided all living things into two kingdoms: _____ and _____.
- Up until the 1960’s, textbooks used the 2 Kingdom System to describe the living world.

However...

- Linnaeus developed his system at a time when the _____ world was a new discovery.
- Many one-celled organisms, such as _____, don't fit well in a 2 Kingdom system.

Another problem...

- What are some other issues that you can think of with a classification system that is based on appearance?

Example:

Analogous structures:

_____ to a common challenge

Homologous structures:

_____ similarities

Classifying by Common Descent

- Darwin's contribution, the Theory of _____, suggested that all living organisms are related by _____.
- If we can understand patterns of descent, we can design better nature-based _____ systems

Clues of evolutionary history and _____

Clues: Unique & shared features

-
-
-

Whittaker

- Robert Whittaker, working in the 1940s-70s, was dissatisfied with the old 2-kingdom systems.
- Developed first a 3-kingdom system (_____, _____, _____) and later a 5-kingdom system.
- Whittaker’s system was still essentially hierarchical - with “lower” or “_____” organisms at the bottom.
- 3 Kingdom system - Plant, Animal, Fungi - was based on _____.
- However, Whittaker was reaching for a system based on _____: _____ ancestry.

Domains

- More recently, a new taxonomic level has been added above Kingdoms: _____.
- Living things are divided into three non-hierarchical Domains:

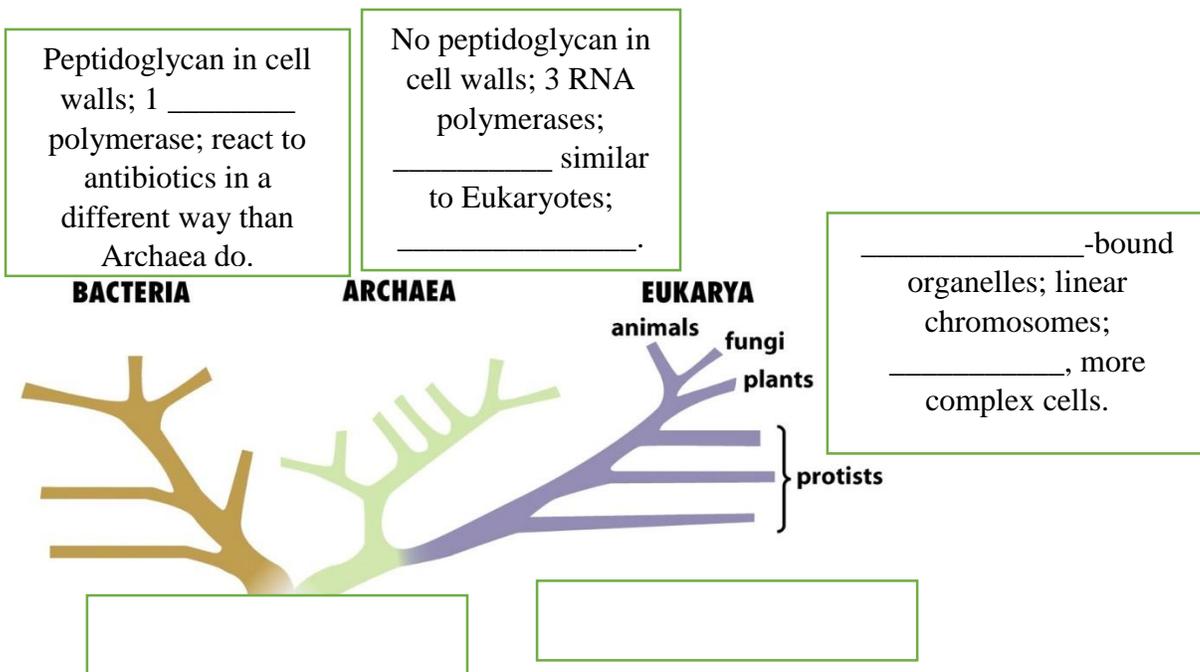


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Kingdoms within Bacteria and Archaea are as yet undecided. Eukaryotic Kingdoms, too, may change.

Table 1: Kingdom Worksheet

Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Cell Type						
Cell Wall						
Body Form						
Nutrition						
Nervous System						
Reproduction						
Locomotion						
Examples						

Scientific Naming

- Why: common names are different around the world, scientific names are universal
- Full classification: _____, _____, _____,
_____, _____, _____
 - Most _____ to most _____
- Scientific naming: *Genus species*
 - _____ or underline
 - Genus first letter capitalized

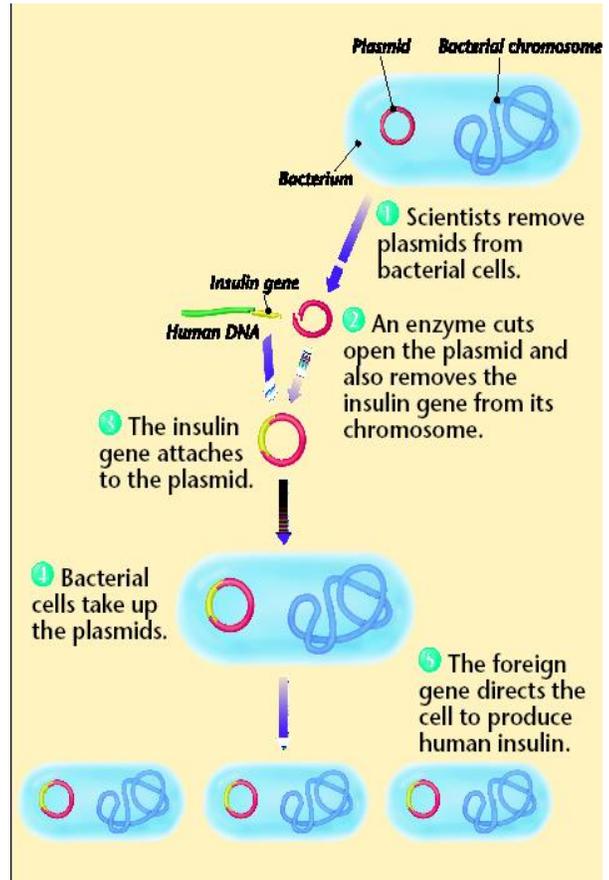
- Species all lowercase
- Examples: _____, _____, _____

Bacteria – the Most _____ Organisms

There are more bacteria in your mouth than there have been people living since the dawn of humans.

What Good Are Bacteria?

- Bacteria are the primary recyclers of materials in the environment, particularly _____.
- Bacteria are also essential for many processes we depend on –
 - _____
 - _____
 - cheese production
 - antibiotic production
 - biotechnological processes like _____ and protein production.
- Bacteria are used to produce _____ and other drugs that people need.
- _____
- _____



Classifying Organisms

- Systematists develop classifications based on _____ relationships. They tend to look at:
 - _____ - a traditional method.
 - _____ **data** - to examine genetic similarities and differences.

Anatomy

- Anatomical comparisons help identify organisms and can suggest relationships. Anatomy can be _____ in fossils as well as modern organisms.
- Drawback: _____ traits in unrelated organisms can be misleading.
- Both _____ and _____ features may be important.

Molecular

- _____ analysis can determine how closely two _____ are related and show what genes are shared.
- Drawback: Requires intensive, often _____ lab work; difficult for field workers. Rare to find DNA in _____.

Which of these is a good *phylogenetic* definition of what a species is?

1. A population of organisms whose members look alike.
2. The smallest distinguishable group that contains all the descendants of a single common ancestor
3. A group of organisms living in the same place and using the same sources of food.

When evolutionary biologists say, “Humans and chimpanzees share a common ancestor,” which of these do they mean?

1. Chimpanzees stopped evolving long ago, but humans continued to evolve.
2. Humans came from chimpanzees.
3. Both humans and chimpanzees descend from an extinct primate that lived several million years ago.

Weird Stuff

Viruses

- Small _____ agent that replicates only inside the living cells of other organisms
- Examples: _____, influenza, small pox, chicken pox, herpes, ebola, _____ (infects bacteria)

Viroids

- _____ infectious pathogens know,
- Short strands of circular single-stranded RNA
- Mostly infect _____—chloroplast or nucleus

Even Weirder Stuff

Prions

- Infectious agent
- Misfolded _____ that influences other proteins
- Examples:
 - Creutzfeldt-Jakob disease, _____, fatal familial insomnia, mad cow disease, scrapie (sheep), _____ (deer)
- _____ or the result of consuming infected tissue (nervous tissue)

Which of these qualify as living organisms?

1. Viruses
2. Viroids
3. Prions
4. None of these

Constructing Trees

- Systematists compare as many features as possible when constructing _____ trees.
- Computers are often used to _____ relatedness between different species.
- New _____ or new understanding of data may change the trees.

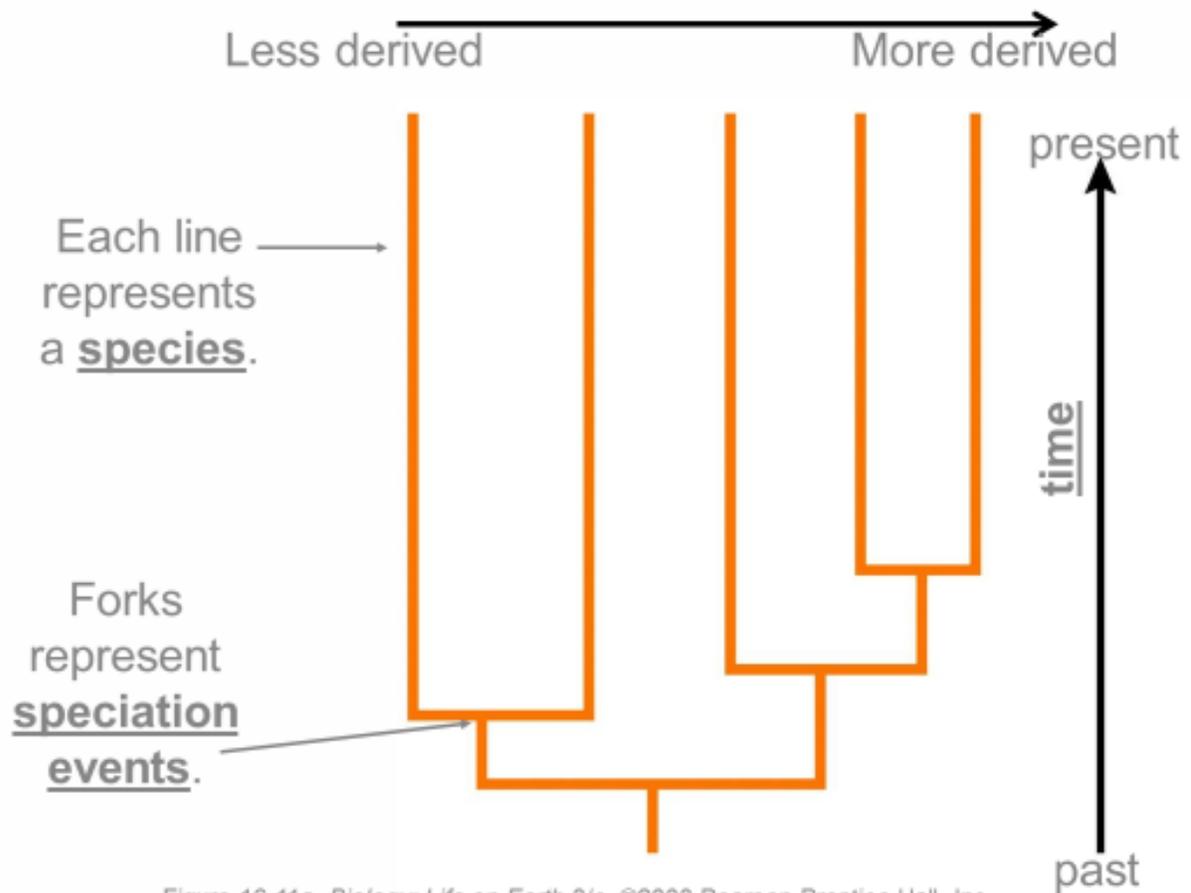
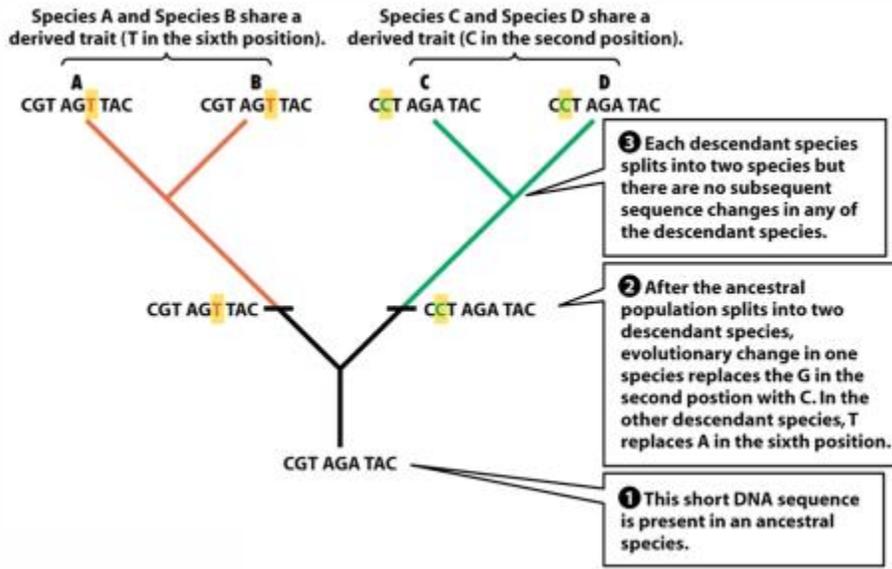
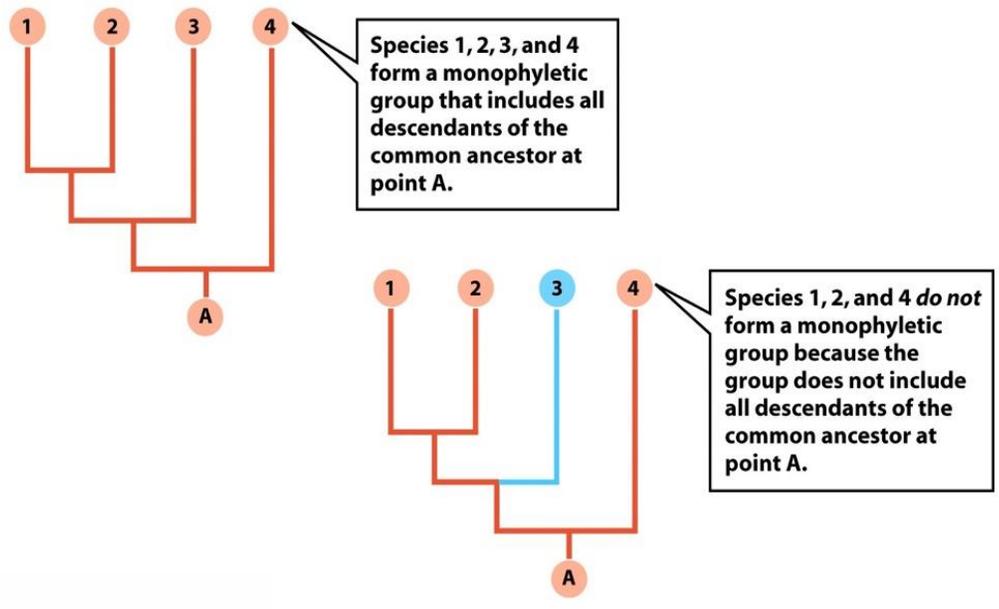


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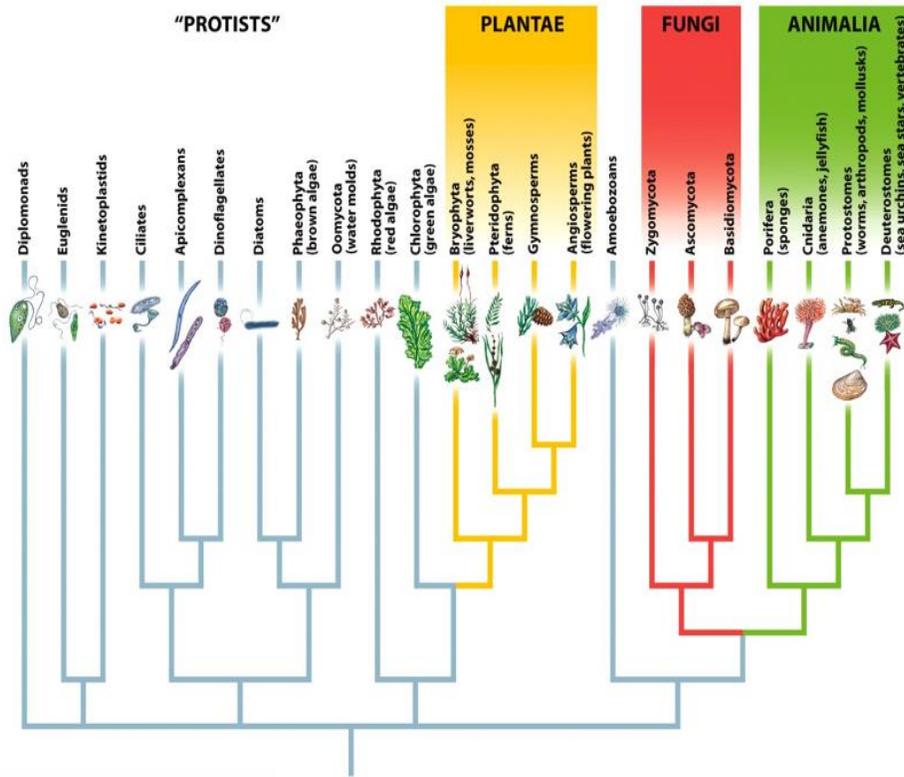


_____ sequences are often used in constructing phylogenetic trees. Ancestral DNA may be inferred from living species. In rare instances, DNA may be recovered from _____.



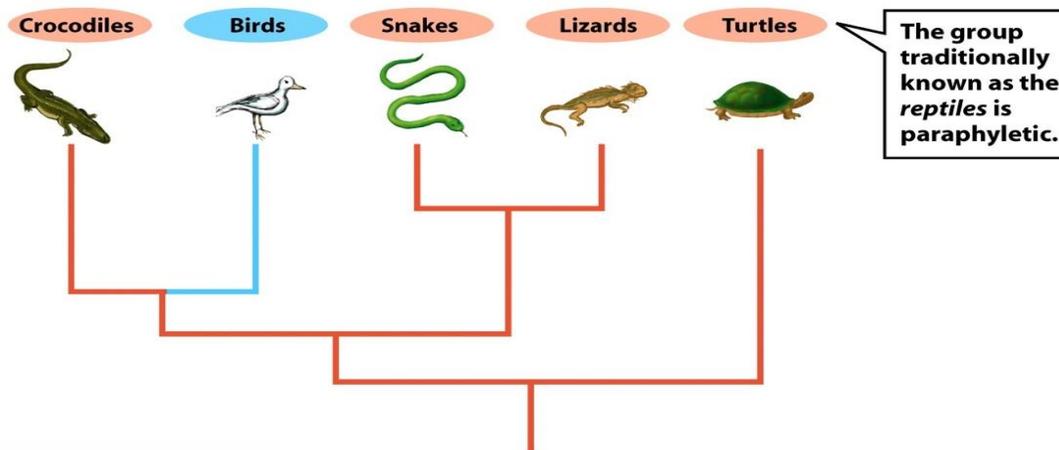
Systematists try to identify groups that are _____: modern species that all appear to have descended from one _____.

Plants, Animals, and Fungi form distinct groups on the _____ branch of the _____ tree.



“Kingdom Protista” turns out to be _____. This group may end up being divided into several _____.

_____ data have shown that some well-known groups, thought to be well-defined, are not monophyletic.

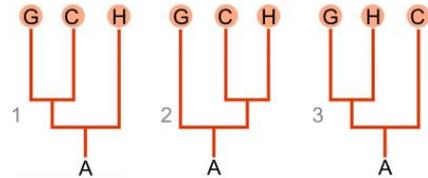


We may have to re-think our ideas about what _____ and reptiles really are!

Suppose a systematist has these DNA sequences from the hemoglobin gene. Which of these species are most closely related to the proposed ancestor? Which are the least related to the ancestor?

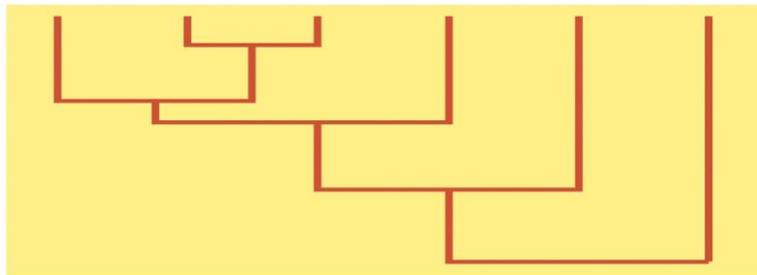
- Chimpanzee:
AGG CCC CTT CCA ACC GGA TTA
- Gorilla:
AGG CCC CTT CCA ACC AGG CC
- Human:
AGG CAT AAA CCA ACC GAT TA
- Proposed ancestor:
AGG CCG GCT CCA ACC AGG CC

• If these primate groups are all related, the systematist knows there are three ways to express the relationships. Which of the following trees best fits the data?

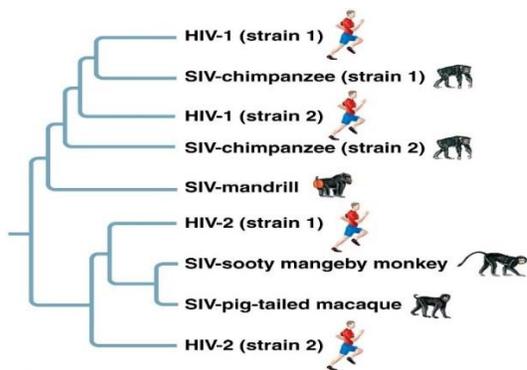


WORK TOGETHER

One well-supported and widely-accepted interpretation of genetic relationships between modern primates.



Not only can we find _____ relationships between organisms, we can also find relationships between the _____ that affect them. This tree shows relationships between AIDS-causing viruses in humans and several modern _____, which helps us understand the host-jumping disease itself.



Remember, trees such as these do not say that humans _____ from other modern primates. “Man came from monkeys” is a common _____ of what evolution means. Phylogenetic trees trace common _____ between groups, and infer shared ancestors based on relationships between modern organisms.

So - humans _____ descend from modern apes or monkeys. Trying to discover where humans *do* come from has been difficult.

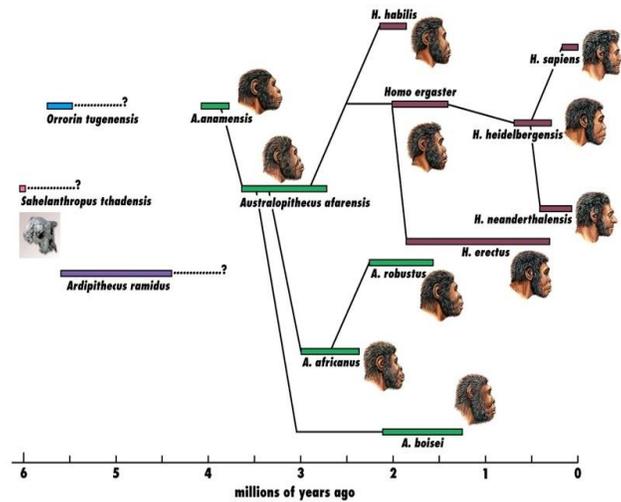
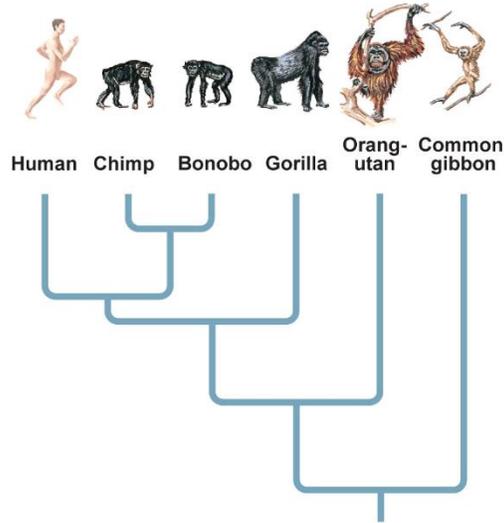


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One difficulty in working out human _____ is that there is only _____ modern species of humans. Also, _____ fossils are rare. The human family tree has many question marks on it!

_____ and _____ genomes have been accumulating genetic change since their ancestral group split at:

Recap

- OLD SYSTEM OF CLASSIFICATION USED _____
- Modern Systematics seeks to classify organisms according to _____.
- Anatomical and _____ data are used to infer relatedness between modern organisms.
- Data from _____ evidence is also used to build phylogenetic trees.

Review

Cladogram- A diagram depicting patterns of shared characteristics among species. Implies evolutionary relationships.

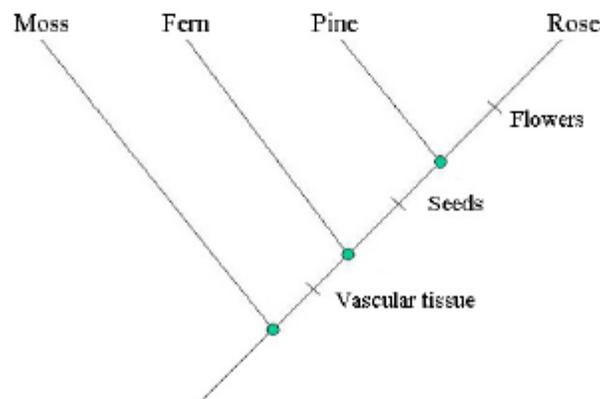
In this exercise, you will work with a real-world data set to build a cladogram of some groups of animals. The basic idea is very similar to the phylogeny in Exercise 2, except cladograms only show evolutionary relationships. Cladograms do not show an evolutionary time scale as seen in phylogenetic trees.

The data used in a cladogram is binary (1 means present, 0 means absent). The below example shows how plant data can be used to determine a simple plant cladogram.

Binary data table for plants

Organism	Vascular tissue	Chlorophyll	Seeds	Flowers	Total derived traits
Moss	0	1	0	0	1
Pine tree	1	1	1	0	3
Rose	1	1	1	1	4
Fern	1	1	0	0	2
Total shared traits	3	4	2	1	na

1. Determine the “outgroup”. The outgroup is the organism with the fewest number of derived traits. This is the group all other groups are compared to.
2. Starting with a diagonal line, the out-group is placed on the first branch. Just past the first branch, the most common derived trait is listed; in this case vascular tissue, which is composed of tube-like cells. The branching point or node on a cladogram marks the point where shared derived characters arose.
3. Next, the second most common derived trait is determined, which in this case is seeds. Ferns lack seeds and are thus placed on the second branch. The third most common derived trait is flowers. Pine trees do not have flowers and are thus placed on the third branch. Flowering plants are placed at the end.



Based on the data given, where would the chlorophyll trait be placed on this tree?