Classification and Systematics

Finding Order in Nature

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

Naturalistic Systematics

- Around the 18th century, naturalists 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 "natural" system, or even if a "natural" system was necessary.

Linnaeus

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

Linnaean System

- Three Kingdoms of nature: Plants, Animals, Minerals.
- Within each Kingdom, organisms are organized into **nested hierarchies**.

Linnaeus' system was considered "artificial," based on observable external 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.

Hierarchical classification is fine, but it must be natural.

Oui, mon professeur, classification should be natural, but a hierarchy is not natural.

Buffon

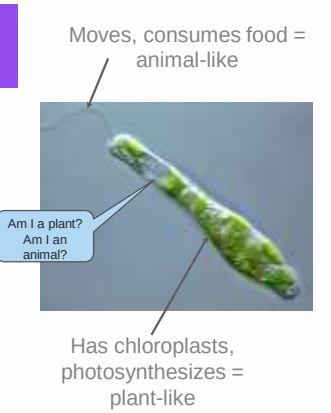
Cuvier

2 Kingdom system

- Linnaeus divided all living things into two kingdoms: Plants and Animals.
- 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 microbial world was a new discovery.
- Many one-celled organisms, such as *Euglena*, don't fit well in a 2 Kingdom system.



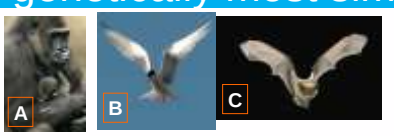
Let's vote!

1. Euglena should be classed as an animal because it moves and can eat food particles.
2. Euglena should be classed as a plant because it photosynthesizes and makes its own food.

Another problem…

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

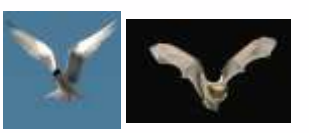
Which pair of organisms is genetically most similar?



1. A is most like B
2. B is most like C
3. ✔ A is most like C

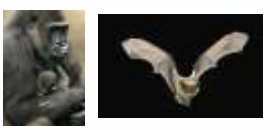
Analogous structures:

Solutions to a common challenge



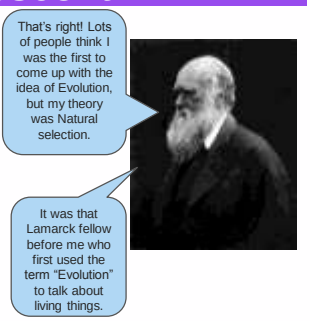
Homologous structures:

Inherited similarities



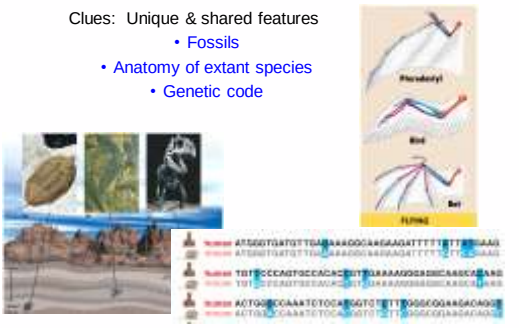
Classifying by Common Descent

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



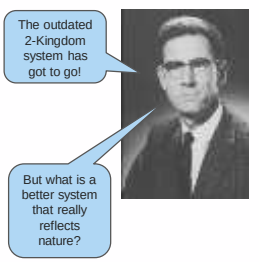
Clues of evolutionary history and **common ancestry**

Clues: Unique & shared features
- Fossils
- Anatomy of extant species
- Genetic code

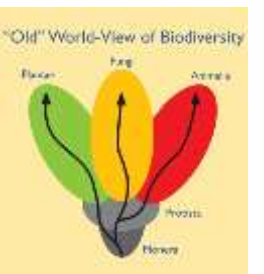


Whittaker

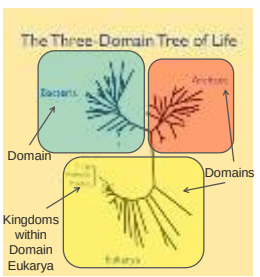
- Robert Whittaker, working in the 1940s-70s, was dissatisfied with the old 2-kingdom systems.
- Developed first a 3-kingdom system (Fungi, Plants, Animals) and later a 5-kingdom system.



- Whittaker's system was still essentially hierarchical - with "lower" or "primitive" organisms at the bottom.
- 3 Kingdom system - Plant, Animal, Fungi - was based on **nutrition**.
- However, Whittaker was reaching for a system based on **phylogeny**: evolutionary ancestry.



Domains

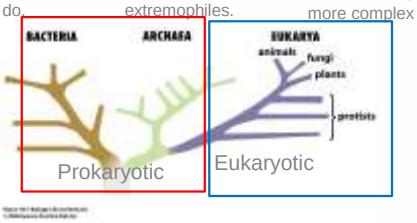


- More recently, a new taxonomic level has been added above Kingdoms: Domains.
- Living things are divided into three non-hierarchical Domains:
  - **Bacteria**
  - **Archaea**
  - **Eukarya**

Peptidoglycan in cell walls; 1 RNA polymerase; react to antibiotics in a different way than Archaea do.

No peptidoglycan in cell walls; 3 RNA polymerases; enzymes similar to Eukaryotes; extremophiles.

Membrane-bound organelles; linear chromosomes; larger, more complex cells.



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

Scientific Naming

- Why: common names are different around the world, scientific names are universal
- Full classification: Kingdom, phylum, class, order, genus, species
  - Most inclusive to most exclusive
- Scientific naming: *Genus species*
  - Italicize or underline
  - Genus first letter capitalized
  - Species all lowercase
  - Examples: *Homo sapiens*, Canis lupus, *Felis catus*

Which of these groups is prokaryotic?

1. Plants
2. Animals
3. Protists
4. Fungi
5. ✔ Bacteria
6. Answers 3, 4, and 5
7. All except the Animals

Bacteria – the Most Abundant Organisms

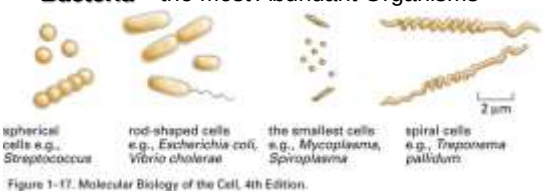


Figure 1–17. Molecular Biology of the Cell, 4th Edition.

Bacteria (*Staphylococcus aureus*; yellow spheres) adhering to nasal cilia.

E. Coli bacteria

Mycoplasma hyopneumoniae

Borrelia burgdorferi, the bacterium that causes Lyme disease.

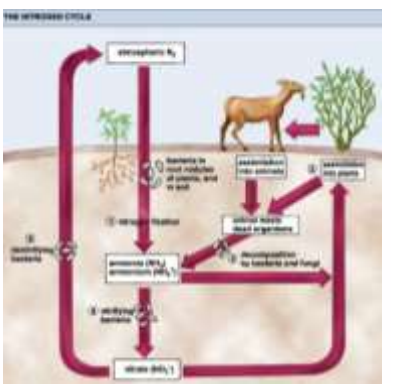
There are more bacteria in your mouth than there have been people living since the dawn of humans.

What Good Are Bacteria?

Bacteria are the **primary recyclers of materials in the environment**, particularly **nitrogen.**

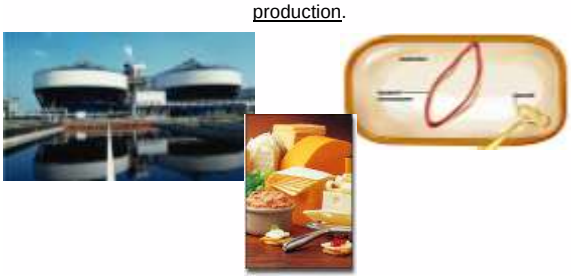
Newsflash!!!

Bacteria discovered that can do **photosynthesis!**



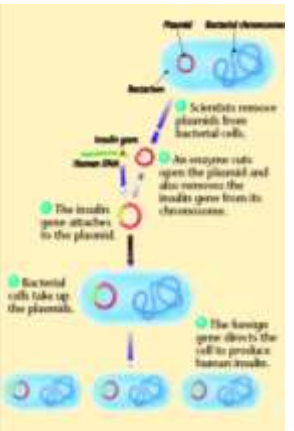
What Good Are Bacteria?

Bacteria are also essential for many processes we depend on – sewage treatment, clean up oil spills, cheese production, antibiotic production, and biotechnological processes like gene cloning and protein production.



Bacteria are used to produce **insulin** and other drugs that people need.

BACTERIAL TRANSFORMATION

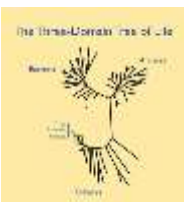


To what Domain do moss plants and ferns belong?

1. Bacteria
2. Archaea
3. ✔ Eukarya

Based on the diagram we looked at earlier, which group of organisms is most diverse?

1. Animals
2. Plants
3. ✔ Bacteria



Classifying Organisms

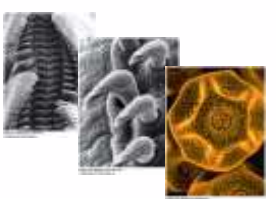
- Systematists develop classifications based on evolutionary relationships. They tend to look at:
  - **anatomy** - a traditional method.
  - **molecular data** - to examine genetic similarities and differences.

Anatomy

•Anatomical comparisons help identify organisms and can suggest relationships. Anatomy can be see in fossils as well as modern organisms.

•Drawback: Analogous traits in unrelated organisms can be misleading.

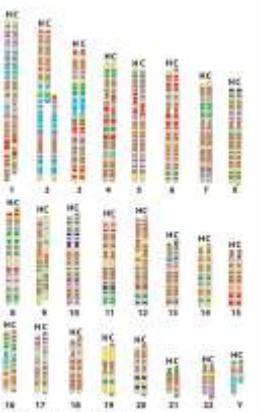
Both microscopic and macroscopic features may be important.



Molecular

•DNA analysis can determine how closely two populations are related and show what genes are shared.

•Drawback: Requires intensive, often expensive lab work; difficult for field workers. Rare to find DNA in fossils.



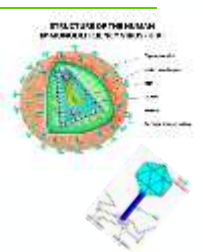
Which of these is a good ***phylogenetic*** definition of what a species is?

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

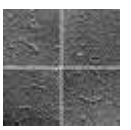
WORK TOGETHER

Weird Stuff



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

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



Even Weirder Stuff

Prions
- Infectious agent
- Misfolded protein that influences other proteins
- Examples:
  - Creutzfeldt-Jakob disease, kuru, fatal familial insomnia, mad cow disease, scrapie (sheep), chronic wasting (deer)
- Inherited 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 phylogenetic trees.
- Computers are often used to compare relatedness between different species.
- New data or new understanding of data may change the trees.

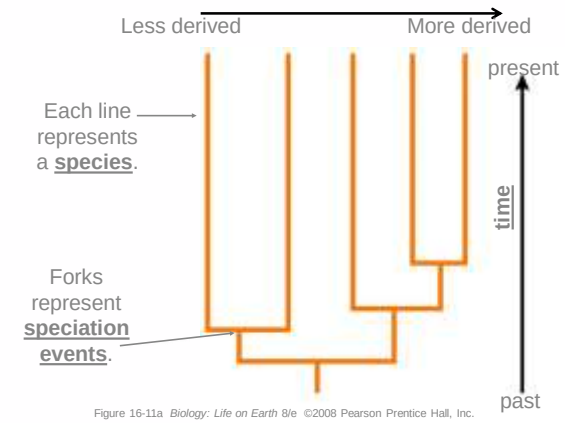
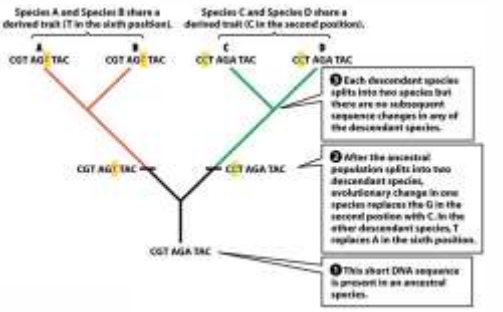
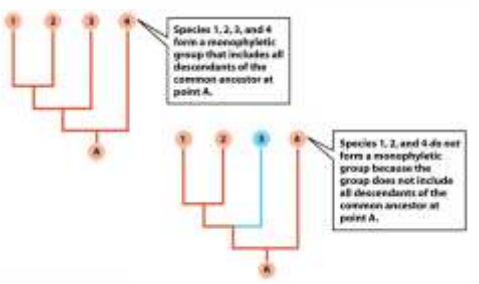


Figure 16-11a *Biology: Life on Earth 8/e* ©2008 Pearson Prentice Hall, Inc.

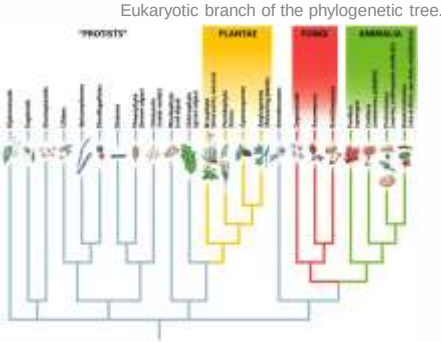


DNA sequences are often used in constructing phylogenetic trees. Ancestral DNA may be inferred from living species. In rare instances, DNA may be recovered from fossils.



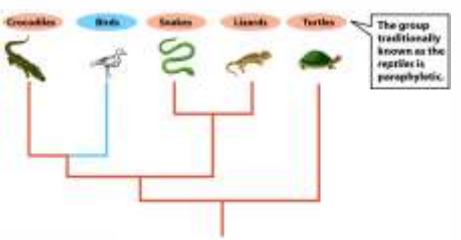
Systematists try to identify groups that are **monophyletic**: modern species that all appear to have descended from one common ancestor.

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



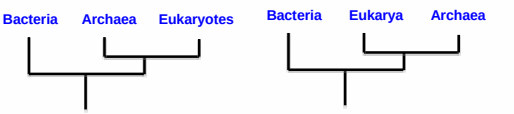
"Kingdom Protista" turns out to be **polyphyletic**. This group may end up being divided into several Kingdoms.

Molecular 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 birds and reptiles really are!

Do these phylogenies show the same hypotheses?

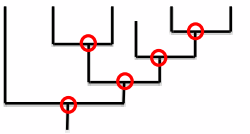


1. Yes
2. No ✔

True or False: Derived (more recent) organisms are always more complex, better, and more advanced than ancestral organisms.

1. True
2. ✔ False

What's happening at the marked spots on this tree?

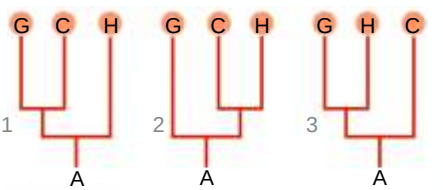


1. Extinction
2. ✔ Speciation
3. Selection
4. Mutation

- 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

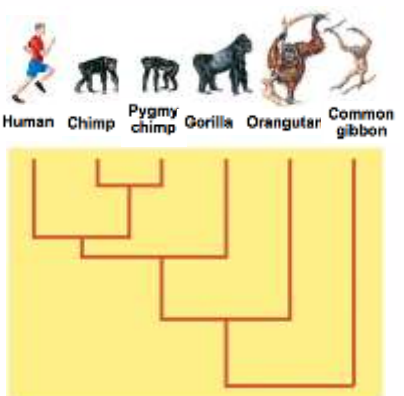
WORK TOGETHER

- 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?

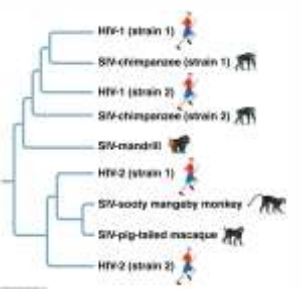


WORK TOGETHER

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

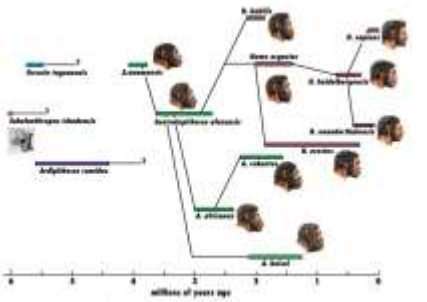


Not only can we find evolutionary relationships between organisms, we can also find relationships between the diseases that affect them. This tree shows relationships between AIDS-causing viruses in humans and several modern primates, which helps us understand the host-jumping disease itself.



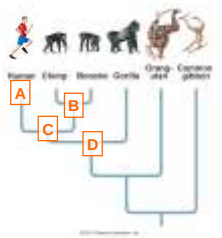
Remember, trees such as these do not say that humans *descend* from other modern primates. “Man came from monkeys” is a common misperception of what evolution means. Phylogenetic trees trace common shared genes between groups, and infer shared ancestors based on relationships between modern organisms.

So - humans do *not* descend from modern apes or monkeys. Trying to discover where humans *do* come from has been difficult.



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

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



1. A
2. B
3. ✔ C
4. D

Recap

- OLD SYSTEM OF CLASSIFICATION USED PHYSICAL CHARACTERISTICS
- Modern Systematics seeks to classify organisms according to ***EVOLUTIONARY RELATIONSHIPS***.
- Anatomical and molecular data are used to infer relatedness between modern organisms.
- Data from fossil evidence is also used to build phylogenetic trees.