Classification disclaimers

The trees we will use are a combination of those on the Tree of Life Web Project (http://tolweb.org/tree/) and Murphy et al (Science (2001) 294: 2348-2351).

Phylogenies are constantly being tweaked and refined.

Some details of some of the following trees may be in dispute.

The phylogeny you get in other courses may therefore differ.
RELATIONSHIPS among ribosomal RNAs (rRNAs) from almost 600 species are depicted. A single line represents the rRNA sequence in one species or a group; many of the lines reflect rRNAs encoded by nuclear genes, but others reflect rRNAs encoded by chloroplast or mitochondrial genes. The mitochondrial lines are relatively long because mitochondrial genes evolve rapidly. Trees derived from rRNA data are rootless; other data put the root at the colored dot, corresponding to the lowest part of the tree on pages 90 and 91.

Uprooting the Tree of Life
Using duplicated genes that predate divergence (Bio 472)

RELATIONSHIPS among ribosomal RNAs (rRNAs) from almost 600 species are depicted. A single line represents the rRNA sequence in one species or a group; many of the lines reflect rRNAs encoded by nuclear genes, but others reflect rRNAs encoded by chloroplast or mitochondrial genes. The mitochondrial lines are relatively long because mitochondrial genes evolve rapidly. Trees derived from rRNA data are rootless; other data put the root at the colored dot, corresponding to the lowest part of the tree on pages 90 and 91.

Uprooting the Tree of Life
Letter

A phylogeny-driven genomic encyclopaedia of Bacteria and Archaea

Dongying Wu1,2, Philip Hugenholtz3, Konstantinos Mavromatis4, Rudiger Pfaff1, Eliane Dalin5, Natalia N. Ivanova6, Victor Kunin7, Lynne Goodwin8, Martin Wu2, Brian J. Tindall9, Sean D. Hopper10, Amrita Pathi11, Athanasios Lykidis12, Stefan Springer13, Iain J. Anderson14, Patrik D’haezeleer15, Adam Zomba16, Mitchell Singer2, Alla Lapidus17, Matt Nolan18, Alex Copeland19, Cliff Han20, Feng Chen21, Jan-Fang Cheng22, Susan Lucas23, Cheryl Kerfeld24, Elke Lang25, Sabine Gronow26, Patrick Chain1,2, David Bruce27, Edward M. Rubin28, Nikos C. Kyrpides29, Hans-Peter Klank30,4, and Jonathan A. Eisen2
Eubacteria (true bacteria)
Archaea (archaebacteria)
Plants (mosses, ferns, seed plants)
Fungi (mushrooms, yeasts)
Ctenophora (comb jellies)
Porifera (sponges)
Cnidaria (jellyfish, anemones, corals)
Nematoda (round worms)
Onychophora (velvet worms)
Arthropoda (insects, spiders, crustaceans, chelicerates)
Annelida (segmented worms)
Mollusca (snails, clams, squids, etc.)
Platyhelminthes (flatworms)
Echinodermata (starfish, sea stars, sea cucumbers, etc.)
Urochordates (tunicates)
Cephalochordates (amphioxus)
Hyperotreti/Myxinidae (hagfish)
Hyperoartia/Petromyzontidae (lampreys)
Chondrichthyes (cartilaginous fish: sharks, rays, etc.)
Actinopterygii (ray-finned fish)
Nematoda (round worms)

NOTES:
Many extinct taxa are not represented on this diagram.
Many extant taxa are not represented on this diagram.
Branch lengths are not to scale.

Turtles were long thought to have evolved from anapsids which are otherwise extinct.

Eubacteria

True bacteria
Mitochondria
Chloroplasts

Cells have cell walls
Cells are not nucleated

Archaea

Archaebacteria, unusual bacteria that live in unusual places

They look just like bacteria, they are distinguished via biochemical and genetic differences

http://www.unm.edu/~astro1
http://www.aquamedicine.no
http://www.ufrsd.net
Fungi (mushrooms, yeasts)

http://www.fastrac.net.au/~nerringillah/
http://www.mykoweb.com/
http://www.wineaccents.com/
Green plants

Green Algae
Mosses
Ferns
Seed plants
  - Gymnosperms (no flowers)
  - Angiosperms (flowering)
Major *phyla* of animals

- Porifera (sponges)
- Ctenophora (comb jellies)
- Cnidaria (jellyfish, anemones, corals)
- Nematoda (round worms)
- Onychophora (velvet worms)
- Arthropoda (insects, spiders, crustaceans)
- Mollusca (snails, clams, squids, etc.)
- Annelida (segmented worms)
- Platyhelminthes (flatworms)
- Chordata (chordates, vertebrates)
- Echinodermata (starfish, sea cucumbers..)

- Ecdysozoa
- Lophotrochozoa

- bilateria
- 3 cells layers

*know them all*
Porifera (sponges)

http://acquari.aquariaonline.net/scuba.htm
Ctenophora
(comb jellies)

http://www.ucmp.berkeley.edu/cnidaria/ctenophora.html
Cnidaria (jellyfish, anemones, corals)
Major *phyla* of animals

- Porifera (sponges)
- Ctenophora (comb jellies)
- Cnidaria (jellyfish, anemones, corals)
- Nematoda (round worms)
- Onychophora (velvet worms)
- Arthropoda (insects, spiders, crustaceans)
- Mollusca (snails, clams, squids, etc.)
- Annelida (segmented worms)
- Platyhelminthes (flatworms)
- Chordata (chordates, vertebrates)
- Echinodermata (starfish, sea cucumbers..)
Dirofilaria immitis in a dog’s heart. This nematode is a major menace to the health of dogs in North America. The adults live in the heart, and the juveniles circulate in the blood where they are picked up and transmitted by mosquitoes.
Onychophora (velvet worms)

http://www.cals.ncsu.edu
Arthropoda (insects, spiders, crustaceans)

**Hexapoda**: insects mostly

**Myriapoda**: millipedes, centipedes

**Crustacea**: crabs, lobsters, shrimp, barnacles

**Chelicerata**: spiders, mites, scorpions, horseshoe crabs, trilobites

[Image sources: http://dr-amy.com]
Mollusca (snails, clams, squids, etc.)

- chiton
- clam
- snail
- nudibranch
- octopus
Annelida (segmented worms)
Platyhelminthes (flatworms)
Major phyla of animals:

- Porifera (sponges)
- Ctenophora (comb jellies)
- Cnidaria (jellyfish, anemones, corals)
- Nematoda (round worms)
- Onychophora (velvet worms)
- Arthropoda (insects, spiders, crustaceans)
- Mollusca (snails, clams, squids, etc.)
- Annelida (segmented worms)
- Platyhelminthes (flatworms)
- Chordata (chordates, vertebrates)
- Echinodermata (starfish, sea cucumbers..)
Echinodermata
(starfish, sea cucumbers...)

starfish

sea urchin

sea cucumber
Chordata (chordates, vertebrates)

- Urochordates (tunicates)
- Cephalochordates (amphioxus)
- Craniata (hagfish, vertebrates)
Craniata (hagfish, vertebrates)

Hyperotreti (Hagfish)

Hyperoartia (Lampreys)

Gnathostomata (vertebrates with jaws)
Gnathostomata (vertebrates with jaws)

- Chondrichthyes (cartilagenous fish: sharks, rays, etc.)
- Actinopterygii (ray-finned fish)
- Sarcopterygii (lobed finned fish)

http://www.moolelo.com/
Sarcopterygii
(lobed finned fish)

Dipnoi (lungfish)

Terrestrial vertebrates
(mammals, reptiles, birds, amphibians)

Neoceratodus (Australia)
Direct descendant of ancient lungfish
Cannot withstand complete drying up of water

Lepidosiren (South America)
Side branch of lungfish evolution
Can burrow in mud when water dries up

Protopterus (Africa)
Side branch of lungfish evolution
Can burrow in mud when water dries up

FIGURE 26-11
The three surviving lungfishes. The approximate range of each genus is shown on map inserts.
Sarcopterygii
(lobed finned fish)

Figure 17.7  Fin bones in lobe-finned fish from the Devonian *Eusthenopteron*, the genus pictured here, had fins containing bones in the typical tetrapod limb arrangement. In the detailed drawing of the fins, dashed lines indicate elements that have not yet been found in fossilized specimens. These are inferred to have existed from the position and structure of adjoining elements. Modified from Carroll (1988) and Jarvik (1980).
Anura

Caudata

Gymnophiona

frogs

and toads
Salamanders and newts

Members of the largest family of salamanders, the Plethodontidae, do not possess lungs and are therefore known as lungless salamanders. Because they respire through their skin and the lining of the mouth, they must live in moist habitats; both the two-lined salamander Eurycea bislineata carrigera (left) and the red salamander Pseudotriton ruber (below) are found near brooks and springs in central to eastern North America.

Two fully aquatic salamanders, the mudpuppy Necturus maculosus (top) and the dwarf eel Pseudobranchiatus shiilus (above).
Turtles: **Cryptodira** (vertical retraction) **Pleurodira** (side necked)

Galapagos tortoise
*Chelonia mydas*

Alligator snapping turtle
side-necked turtle, pleurodira
Crocodiles and alligators

Gharial
Crocodile
Oronoco crocodile and capybara
Ornithischia (bird-hipped herbivores)

all dino pictures by Artist Joe Tucciarone, http://members.aol.com/Dinoplanet/dinosaur.html
Sauropodomorpha
(long necked herbs)
Theropoda (bipedal carnivores)
Class = aves

Paleognathae

Neognathae
Paleognathae
Neognathae

Ratities and tinamous

tinamous
emu
cassowary

kiwi
all other birds

- Paleognathae
- Neognathae

emperor penguins
Sphenodontida (tuatara)
Iguana

http://faculty.uca.edu/~johnc

http://www.travel-library.com
Snakes, amphisbaenians, other lizards

- Green mamba
- Bipes, amphisbaenian
- Frill-necked lizard
- Chameleon
Monotremata, 3 species
(platypus, echidna)

Marsupialia, 260 species
(kangaroos, wombats, koalas...)

Eutheria (placental mammals)
Orders of mammals

Cetartiodactyla

Eutheria

Cetacea (whales, dolphins)

Artiodactyla (pigs, deer, goats, hippos, camel) *even toed ungulates*

Perissodactyla (horses, tapirs, rhino) *odd toed ungulates*

Carnivora (dogs, cats, bears, raccoons, weasels, hyenas, seals, walrus)

Pholiodota (pangolins)

Chiroptera (bats)

Insectivora (shrews, hedgehogs, moles)

Rodentia (rodents)

Lagomorpha (rabbits, hares, pikas)

Dermoptera (flying lemurs)

Scandentia (tree shrews)

Primates (monkeys, apes, humans)

Xenartha (anteaters, sloths, armadillos)

Macroscelidea (elephant shrews)

Tubulidentata (aardvark)

Sirenia (manatees, dugong, sea cow)

Hyracoidea (the hyrax)

Proboscidea (elephants)

Marsupialia (kangaroos, wombats, koalas...)

Monotremata (platypus, echidna)

Afrotheria

Glires

Lagomorpha (rabbits, hares, pikas)

Dermoptera (flying lemurs)

Scandentia (tree shrews)

Primates (monkeys, apes, humans)

Xenartha (anteaters, sloths, armadillos)

Macroscelidea (elephant shrews)

Tubulidentata (aardvark)

Sirenia (manatees, dugong, sea cow)

Hyracoidea (the hyrax)

Proboscidea (elephants)

Marsupialia (kangaroos, wombats, koalas...)

Monotremata (platypus, echidna)
Cetacea: whales, dolphin

**Mysticeti:**
2 blowholes
most are large
no teeth, keratin sheets (baleen) instead.

**Odontoceti:**
1 blowhole
most are smaller
Teeth made from enamel
Artiodactyla (pigs, deer, goats, hippos, camel) 
even toed ungulates

bison

gazelle

yak

boar

giraffe

hippo
Perissodactyla (horses, tapirs, rhino)
odd toed ungulates

rhino

zebra

tapir
Carnivora (dogs, cats, bears, raccoons, weasels, hyenas, seals, walrus)

Felines

Wolverine

Seal
Pholiodota (pangolins)
Chiroptera (bats)

false vampire

Honduran tent bat

vampire
Insectivora (shrews, hedgehogs, moles)

- hedgehog
- water shrew
- solenodon
Orders of mammals

- Cetartiodactyla
  - Cetacea (whales, dolphins)
  - Artiodactyla (pigs, deer, goats, hippos, camel) *even toed ungulates*
  - Perissodactyla (horses, tapirs, rhino) *odd toed ungulates*
  - Carnivora (dogs, cats, bears, raccoons, weasels, hyenas, seals, walrus)
  - Pholiodota (pangolins)
  - Chiroptera (bats)
  - Insectivora (shrews, hedgehogs, moles)
  - **Rodentia (rodents)**
  - Lagomorpha (rabbits, hares, pikas)
  - Dermoptera (flying lemurs)
  - Scandentia (tree shrews)
  - Primates (monkeys, apes, humans)
  - Xenarthra (anteaters, sloths, armadillos)
  - Macroscelidea (elephant shrews)
  - Tubulidentata (aardvark)
  - Sirenia (manatees, dugong, sea cow)
  - Hyracoidea (the hyrax)
  - Proboscidea (elephants)
  - Marsupialia (kangroos, wombats, koalas...)
  - Monotremata (platypus, echidna)

- Eutheria

- Glires

- Afrotheria
Rodentia (rodents)

- beaver
- naked mole rat
- capybara
- rat
Lagomorpha (rabbits, hares, pikas)

Artic hare

Pika

Pikachu
Dermoptera (flying lemurs)
Scandentia
(tree shrews)
Primates
- monkeys
- apes
- humans

human

lemur

howler monkeys

orangutan
Xenartha/Edentata (Anteaters, sloths, armadillos)

- Sloth
- Anteater
- Armadillo
- Silky anteater
- Sloth
Orders of mammals

- Cetartiodactyla
  - Cetacea (whales, dolphins)
  - Artiodactyla (pigs, deer, goats, hippos, camel) *even toed ungulates*
  - Perissodactyla (horses, tapirs, rhino) *odd toed ungulates*
  - Carnivora (dogs, cats, bears, raccoons, weasels, hyenas, seals, walrus)
  - Pholiodota (pangolins)
  - Chiroptera (bats)
  - Insectivora (shrews, hedgehogs, moles)
  - Rodentia (rodents)
  - Lagomorpha (rabbits, hares, pikas)
  - Dermoptera (flying lemurs)
  - Scandentia (tree shrews)
  - Primates (monkeys, apes, humans)
  - Xenartha (anteaters, sloths, armadillos)
  - Macroscelidea (elephant shrews)
  - Tubulidentata (aardvark)
  - Sirenia (manatees, dugong, sea cow)
  - Hyracoidea (the hyrax)
  - Proboscidea (elephants)
  - Marsupialia (kangroos, wombats, koalas...)
  - Monotremata (platypus, echidna)

- Glires

- Eutheria

- Afrotheria
Macroscelidea (elephant shrews)
Tubulidentata (aardvark)
Sirenia (manatees, dugong, sea cow)
Hyracoidea (the hyrax)
Proboscidea (elephants)
Marsupialia (kangaroos, wombats, koalas...)

- Feathertail glider
- Sugar glider
- Koala
- Baby
Marsupialia (kangaroos, wombats, koalas...)

wombat

kangaroo