

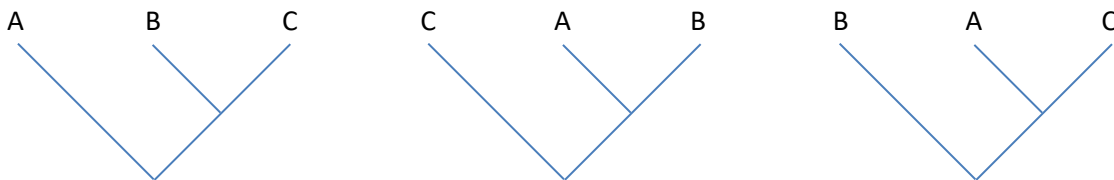
Three-taxon analysis

BIO 123 Section 2, Spring 2017

Introduction

Phylogenetic analysis of dozens of species and hundreds of phenotypic features or thousands of DNA base pairs is computationally intensive. Not only does it require computers, some problems can take hours to run even on a fast computer. And when you're done, you pretty much have to accept the computer's analysis—there's no way to check it by hand.

But most complex problems can be broken down into simple pieces, and phylogenetic analysis is no exception. The simplest piece is called a three-taxon analysis, and it involves looking at the three possible three-taxon statements to see which is best-supported by the data. Here are those statements depicted graphically:



This will probably seem familiar as the basis of the example used in lecture, with the three species *Gymnogyps californianus*, *Equus caballus*, and *Myotis californicus*.

When using three-taxon analysis to reconstruct phylogeny, you wouldn't already know the relationships, and you wouldn't know which shared features were apomorphic, which were plesiomorphic, and which were homoplastic. For this exercise, you'll be approaching it from a different direction. For the three species you've been assigned, the best-supported ("correct") cladogram can be obtained from the literature, either as an actual cladogram, or, more often, by their positions in a taxonomy formed from monophyletic groups. Your job is to find the apomorphies that support the cladogram.

You will be haphazardly assigned your three species from a list, appended below. You will have a "grade" in Blackboard called "3-taxon #". Look for that number on the list, and those are your species.

How to succeed

Here are some suggestions and safety tips to help you out:

- **Read and follow the directions.**
- Make sure to transcribe information accurately. A misspelled or un-italicized scientific name is wrong.

- Don't be afraid to use Wikipedia. Its articles about individual species are generally accurate and often well-written. Every species name in the list should take you to its own Wikipedia page; if it doesn't, let me know.
- Don't guess at the synapomorphy that unites two of your three species; you will almost always be wrong. If you are having trouble finding a reference for the synapomorphy, check with me early.
- Synapomorphies are actual features, not types of features. For example, "lactation" is a synapomorphy; "Method of feeding the young" isn't. "Feathers" is a synapomorphy; "body covering" isn't. "Possession of a unique inverted repeat in the chloroplast genome" is a synapomorphy; "DNA" isn't (at least at that level). "Articulating premaxilla" is a synapomorphy; "skull structure" isn't. If you're not sure, ask yourself whether your outgroup also feeds its young, has body covering, DNA, and a skull. If it does, you're not looking at a synapomorphy for the two most related species.
- Use the template. It ensures that you've put in all the necessary information, and it makes grading easier for me. If you have some reason not to use the template, try to duplicate it as closely as possible.
- **Do not** submit the assignment in paragraph form. It obscures the information, making it exponentially harder for me to grade, so I won't grade it and will record a zero for the assignment.
- **Do not** include photographs. If a visual is absolutely necessary to make a point, put in a web link. I will deduct 5% of the maximum possible grade for each photograph included.
- Did I mention to follow directions?

Required information

1. The scientific name for each species, as given in the list. Using the template, put the most distant relative in the left column, the one of the close relatives that shares a homoplasy or plesiomorphy with the distant relative in the middle column, and the other closest relative in the right column.
2. A common name for each of your three species. Wikipedia is a good source for most. If there is more than one common name (this is not uncommon), you only need to pick one. Many obscure organisms have no common name. If that is the case with yours, enter "common name not listed". I *will* check the Wikipedia article if you do, so don't just guess at it.
3. For each of your species, list its place in the taxonomic hierarchy. Minimally, it will include family (remember that the genus name is already built into the binomial), order, class, and phylum. There may be other levels, including unranked clades. You must include any of those other levels that you use for determining the cladogram and synapomorphy. Levels that you don't use can be left out, but there's no harm in including them. Wikipedia is again a good source—it is generally up-to-date, and the editors work to make the "taxoboxes" consistent across related groups. You can arrange from most inclusive to least inclusive, or least inclusive to most inclusive, but you must be consistent across all three.

4. Because the phylogenetic relationships were used to make the taxonomy, the taxonomy tells you the phylogenetic relationships (this isn't always true, but it is for all the sets of three species that I chose for this assignment). Using this information, show which of the three statements is the correct phylogeny (as currently interpreted). You may draw a tree, but you can also show the same information with parentheses:

(*Gymnogyps californianus* (*Equus caballus*, *Myotis californicus*))

5. Okay, that was the easy part. Now you have to find and list at least one synapomorphy that shows that two of your species are more closely related to each other than either is to the third. In the case above, the two mammals are, well, mammals, and they share all the apomorphies that distinguish mammals. Easy-peasy. But what if, instead of *Myotis californicus*, you were given *Tapirus terrestris*. It and *Equus caballus* are both members of the order Perissodactyla, so you might think that you would need the synapomorphies of that order. And if your third species were *Mus musculus* (another mammal), you would. But *Gymnogyps californianus* isn't a mammal, so you could still use the mammal synapomorphies in this example. You can use whichever taxonomic level provides the easiest-to-find synapomorphies, as long as two of the species share it, and the third doesn't.

Because a lot of phylogenetic analysis these days is based on DNA, and the analysis of DNA sequences doesn't really generate lists of synapomorphies, in some cases you may find only a single synapomorphy to unite two of your three species. But you should always try to find more. If I can think of several off the top of my head, one won't be enough.

6. The next part is actually easier, but it may require some creativity. List a single feature that *one* of your two closest-related species shares with the most distant species. In the case of our example, it would be wings, shared by *Gymnogyps californianus* and *Myotis californicus*. In our example, wings is homoplastic, but in other cases you might choose a plesiomorphy. For example, *Carnegiea gigantea* and *Yucca brevifolia* are both flowering plants, more closely related than either is to *Ephedra nevadensis*, but *Carnegiea gigantea* and *Ephedra nevadensis* share the feature of two cotyledons (*Yucca brevifolia* has one), which is the ancestral state in the seed plants.

You may have to stretch to find this feature. Some other possibilities are habitat (salt water vs. fresh water), structure (aseptate filaments vs. septate), or even color (red lophophore vs. colorless lophophore).

7. And last, for each of your species, write down what you think is the most interesting or unexpected thing about it. This is your personal opinion, so as long as the information is correct, whatever you choose is right.
8. Don't forget references:
 - a. For every Wikipedia article you use, list the title (I should be able to copy it, paste it into the Wikipedia search box, and go directly to your article), and the date you accessed it (so that if it changed, I can go to the page history and see the page you saw). You don't need to include the three species names; I assume you will have looked at them, and I

looked at every one of them when I developed the assignment. You *shouldn't* include any articles that were dead ends, or otherwise not helpful.

- b. For any reference not in Wikipedia, provide a URL that I can use to access it on the web. If you use the textbook, just copy and paste the citation from the course syllabus.

Submitting your assignment

Go to this course in Blackboard and open the Assignments page. Find “Three-taxon analysis” and click “View/Complete”. Make sure “Submit:” at the top says “Single File Upload”. Enter the requested information (use Three-taxon analysis as the title), and select your file. Click on the Upload button at the bottom of the form.

An Example

Be sure to put the two closest relatives in the two columns on the right. Note that if we switched *Myotis californicus* and *Equus caballus*, it would appear that horses have wings.

1	<i>Gymnogyps californianus</i>	<i>Myotis californicus</i>	<i>Equus caballus</i>
2	California condor	California myotis	horse
3	Kingdom: Animalia Phylum: Chordata Class: Aves Order: Cathartiformes Family: Cathartidae	Kingdom: Animalia Phylum: Chordata Class: Mammalia Order: Chiroptera Family: Vespertilionidae	Kingdom: Animalia Phylum: Chordata Class: Mammalia Order: Perissodactyla Family: Equidae
4	<i>(Gymnogyps californianus (Myotis californicus, Equus caballus))</i>		
5		Hair, lactation, three bones in the middle ear, cheekbones	
6	Wings (homoplasy)		
7	State Bird of California	Tiny feet	Domestic animal
8a	Mammal Bird		
8b	Freeman, S., et al. 2014. <i>Biological Science</i> , 5th Edition. Pearson.		

This table, not filled out, is also in the template, with instructions on the second page.

List of taxa

Choose the number that corresponds to the number assigned to you in Blackboard.

1	<i>Saccharomyces cerevisiae</i>	<i>Agaricus bisporus</i>	<i>Batrachochytrium dendrobatidis</i>
2	<i>Crotalus oreganus</i>	<i>Agkistrodon piscivorus</i>	<i>Python regius</i>
3	<i>Ailuropoda melanoleuca</i>	<i>Ailurus fulgens</i>	<i>Ursus arctos</i>
4	<i>Pseudacris hypochondriaca</i>	<i>Ambystoma mexicanum</i>	<i>Xenopus laevis</i>
5	<i>Salmo salar</i>	<i>Amia calva</i>	<i>Huso huso</i>
6	<i>Caulophacus elegans</i>	<i>Amoeba proteus</i>	<i>Allomyces macrogynus</i>
7	<i>Gloeocapsa magma</i>	<i>Anabaena circinalis</i>	<i>Frankia alni</i>
8	<i>Bertholletia excelsa</i>	<i>Anacardium occidentale</i>	<i>Mangifera indica</i>
9	<i>Scutigera coleoptrata</i>	<i>Anadenobolus monilicornis</i>	<i>Scolopendra heros</i>
10	<i>Telopea speciosissima</i>	<i>Anigozanthos manglesii</i>	<i>Swainsona formosa</i>
11	<i>Archilochus colubris</i>	<i>Apus apus</i>	<i>Apteryx haastii</i>
12	<i>Daphnia pulex</i>	<i>Armadillidium vulgare</i>	<i>Artemia salina</i>
13	<i>Artemia salina</i>	<i>Armadillidium vulgare</i>	<i>Callinectes sapidus</i>
14	<i>Solanum tuberosum</i>	<i>Artemisia dracunculus</i>	<i>Raphanus sativus</i>
15	<i>Cyperus papyrus</i>	<i>Arundo donax</i>	<i>Pennisetum glaucum</i>
16	<i>Elgaria multicarinata</i>	<i>Atractosteus spatula</i>	<i>Macrochelys temminckii</i>
17	<i>Latrodectus geometricus</i>	<i>Atrax robustus</i>	<i>Pycnogonum stearnsi</i>
18	<i>Vaucheria litorea</i>	<i>Bacillaria paxillifer</i>	<i>Bigelowiella natans</i>
19	<i>Clostridium perfringens</i>	<i>Bacillus anthracis</i>	<i>Escherichia coli</i>
20	<i>Periphylla periphylla</i>	<i>Bergtrollus dzimbowski</i>	<i>Branchiostoma floridae</i>
21	<i>Sylvicapra grimmia</i>	<i>Bison bison</i>	<i>Antilocapra americana</i>
22	<i>Helicobacter pylori</i>	<i>Borrelia burgdorferi</i>	<i>Treponema pallidum</i>
23	<i>Cassytha filiformis</i>	<i>Botrychium lunaria</i>	<i>Pseudotsuga macrocarpa</i>
24	<i>Cerastoderma edule</i>	<i>Busycon carica</i>	<i>Lobatus gigas</i>
25	<i>Papilio rutulus</i>	<i>Caenorhabditis elegans</i>	<i>Octopus bimaculatus</i>
26	<i>Calypte anna</i>	<i>Caiman crocodilus</i>	<i>Iguana iguana</i>
27	<i>Aquilegia caerulea</i>	<i>Calochortus nuttallii</i>	<i>Cypripedium reginae</i>
28	<i>Oryctolagus cuniculus</i>	<i>Cavia porcellus</i>	<i>Mesocricetus auratus</i>
29	<i>Coenagrion puella</i>	<i>Ceratitis capitata</i>	<i>Aedes aegypti</i>
30	<i>Orcinus orca</i>	<i>Choeropsis liberiensis</i>	<i>Hippopotamus amphibius</i>
31	<i>Closterium setaceum</i>	<i>Corallina officinalis</i>	<i>Trentepohlia aurea</i>
32	<i>Micropterus salmoides</i>	<i>Corvus corax</i>	<i>Turdus merula</i>
33	<i>Pinus monophylla</i>	<i>Cycas revoluta</i>	<i>Sequoia sempervirens</i>
34	<i>Orycteropus afer</i>	<i>Cyclopes didactylus</i>	<i>Myrmecophaga tridactyla</i>
35	<i>Stachys affinis</i>	<i>Cynara cardunculus</i>	<i>Helianthus tuberosus</i>
36	<i>Procyon lotor</i>	<i>Dasyopus novemcinctus</i>	<i>Canis latrans</i>
37	<i>Mus musculus</i>	<i>Dasyopus novemcinctus</i>	<i>Sarcophilus harrisii</i>
38	<i>Acrasis rosea</i>	<i>Dictyostelium discoideum</i>	<i>Lycogala epidendrum</i>

39	<i>Protonotaria citrea</i>	<i>Dipodomys ingens</i>	<i>Rana muscosa</i>
40	<i>Vaucheria litorea</i>	<i>Elysia chlorotica</i>	<i>Ectocarpus siliculosus</i>
41	<i>Sequoia sempervirens</i>	<i>Ephedra sinica</i>	<i>Selaginella lepidophylla</i>
42	<i>Viola cucullata</i>	<i>Epigea repens</i>	<i>Cypripedium acaule</i>
43	<i>Equisetum arvense</i>	<i>Equus caballus</i>	<i>Trachurus trachurus</i>
44	<i>Equus hemionus</i>	<i>Equus zebra</i>	<i>Diceros bicornis</i>
45	<i>Ictalurus punctatus</i>	<i>Felis catus</i>	<i>Nepeta cataria</i>
46	<i>Amoeba proteus</i>	<i>Fuligo septica</i>	<i>Nosema apis</i>
47	<i>Aphelocoma californica</i>	<i>Gavia immer</i>	<i>Passer domesticus</i>
48	<i>Fulica americana</i>	<i>Gavialis gangeticus</i>	<i>Gavia immer</i>
49	<i>Macrocystis pyrifera</i>	<i>Gelidium sesquipedale</i>	<i>Thalassiosira pseudonana</i>
50	<i>Testudo graeca</i>	<i>Gopherus agassizii</i>	<i>Chelus fimbriata</i>
51	<i>Struthio camelus</i>	<i>Haliaeetus leucocephalus</i>	<i>Catherpes mexicanus</i>
52	<i>Metroxylon sagu</i>	<i>Hatiora salicornioides</i>	<i>Cycas revoluta</i>
53	<i>Pusa sibirica</i>	<i>Helarctos malayanus</i>	<i>Zalophus californianus</i>
54	<i>Lumbricus terrestris</i>	<i>Hirudo medicinalis</i>	<i>Riftia pachyptila</i>
55	<i>Cuscuta pentagona</i>	<i>Hydnora africana</i>	<i>Phoradendron macrophyllum</i>
56	<i>Equisetum hyemale</i>	<i>Juncus effusus</i>	<i>Schoenoplectus californicus</i>
57	<i>Glomus aggregatum</i>	<i>Laccaria bicolor</i>	<i>Pleurotus ostreatus</i>
58	<i>Kallstroemia grandiflora</i>	<i>Larrea tridentata</i>	<i>Eschscholzia californica</i>
59	<i>Psilocybe angustipleurocystidiata</i>	<i>Lophophora williamsii</i>	<i>Turbina corymbosa</i>
60	<i>Pholcus phalangioides</i>	<i>Loxosceles reclusa</i>	<i>Odontodactylus scyllarus</i>
61	<i>Funaria hygrometrica</i>	<i>Lycopodium clavatum</i>	<i>Silene acaulis</i>
62	<i>Suricata suricatta</i>	<i>Lynx rufus</i>	<i>Panthera onca</i>
63	<i>Ziphius cavirostris</i>	<i>Madoqua kirkii</i>	<i>Trichechus manatus</i>
64	<i>Rhincodon typus</i>	<i>Manta birostris</i>	<i>Chiloscyllium indicum</i>
65	<i>Cryptochiton stelleri</i>	<i>Megascolides australis</i>	<i>Chelidonura varians</i>
66	<i>Alopecurus aequalis</i>	<i>Myosurus apetalus</i>	<i>Equisetum arvense</i>
67	<i>Entamoeba gingivalis</i>	<i>Naegleria fowleri</i>	<i>Balamuthia mandrillaris</i>
68	<i>Eschscholzia californica</i>	<i>Nandina domestica</i>	<i>Phyllostachys bambusoides</i>
69	<i>Hydnora triceps</i>	<i>Nuytsia floribunda</i>	<i>Monotropa uniflora</i>
70	<i>Vulpes macrotis</i>	<i>Nyctereutes procyonoides</i>	<i>Procyon lotor</i>
71	<i>Ara ararauna</i>	<i>Nymphicus hollandicus</i>	<i>Melopsittacus undulatus</i>
72	<i>Sylvilagus audubonii</i>	<i>Ochotona princeps</i>	<i>Lepus californicus</i>
73	<i>Pleurobrachia bachei</i>	<i>Orbicella annularis</i>	<i>Nematostella vectensis</i>
74	<i>Oxycomanthus bennetti</i>	<i>Orchesella cincta</i>	<i>Gluvia dorsalis</i>
75	<i>Coriandrum sativum</i>	<i>Origanum vulgare</i>	<i>Stachys affinis</i>
76	<i>Phataginus tricuspis</i>	<i>Orycteropus afer</i>	<i>Manis pentadactyla</i>
77	<i>Ginkgo biloba</i>	<i>Oryza sativa</i>	<i>Tetrapanax papyrifer</i>
78	<i>Atrax robustus</i>	<i>Panulirus interruptus</i>	<i>Paralithodes camtschaticus</i>
79	<i>Vorticella campanula</i>	<i>Paramecium caudatum</i>	<i>Cryptosporidium hominis</i>

80	<i>Pygoscelis papua</i>	<i>Pelecanus erythrorhynchos</i>	<i>Branta canadensis</i>
81	<i>Stentor coeruleus</i>	<i>Pfiesteria piscicida</i>	<i>Phytophthora ramorum</i>
82	<i>Dactylis glomerata</i>	<i>Phleum pratense</i>	<i>Medicago sativa</i>
83	<i>Procambarus clarkii</i>	<i>Photinus pyralis</i>	<i>Stagmomantis carolina</i>
84	<i>Illicium verum</i>	<i>Pimpinella anisum</i>	<i>Glycyrrhiza glabra</i>
85	<i>Crassostrea gigas</i>	<i>Placopecten magellanicus</i>	<i>Helix aspersa</i>
86	<i>Podosphaera fuliginea</i>	<i>Pseudoperonospora cubensis</i>	<i>Cladosporium cladosporioides</i>
87	<i>Ginkgo biloba</i>	<i>Pteridium aquilinum</i>	<i>Cycas circinalis</i>
88	<i>Helarctos malayanus</i>	<i>Pusa sibirica</i>	<i>Tremarctos ornatus</i>
89	<i>Nitella flexilis</i>	<i>Rafflesia arnoldii</i>	<i>Scenedesmus dimorphus</i>
90	<i>Vicugna vicugna</i>	<i>Rangifer tarandus</i>	<i>Camelus ferus</i>
91	<i>Photocorynus spiniceps</i>	<i>Regalecus glesne</i>	<i>Lepisosteus oculatus</i>
92	<i>Ustilago maydis</i>	<i>Rhizopus stolonifer</i>	<i>Pilobolus crystallinus</i>
93	<i>Stemonitis fusca</i>	<i>Rhizopus stolonifer</i>	<i>Chinchilla chinchilla</i>
94	<i>Nautilus pompilius</i>	<i>Sepia officinalis</i>	<i>Argonauta argo</i>
95	<i>Acer rubrum</i>	<i>Sequoia sempervirens</i>	<i>Canis rufus</i>
96	<i>Ipomoea batatas</i>	<i>Solanum tuberosum</i>	<i>Dioscorea esculenta</i>
97	<i>Taricha torosa</i>	<i>Sphenodon punctatus</i>	<i>Neoceratodus forsteri</i>
98	<i>Zerene eurydice</i>	<i>Squalus acanthias</i>	<i>Canis familiaris</i>
99	<i>Dendraster excentricus</i>	<i>Strongylocentrotus purpuratus</i>	<i>Antedon mediterranea</i>
100	<i>Caiman yacare</i>	<i>Struthio camelus</i>	<i>Mellisuga helenae</i>
101	<i>Thomomys bottae</i>	<i>Sylvilagus audubonii</i>	<i>Castor canadensis</i>
102	<i>Erinaceus europaeus</i>	<i>Tachyglossus aculeatus</i>	<i>Geogale aurita</i>
103	<i>Nosema apis</i>	<i>Taphrina pruni</i>	<i>Puccinia graminis</i>
104	<i>Strongylocentrotus purpuratus</i>	<i>Tonicella lineata</i>	<i>Cestum veneris</i>
105	<i>Noctiluca scintillans</i>	<i>Toxoplasma gondii</i>	<i>Euglena gracilis</i>
106	<i>Alexandrium tamarense</i>	<i>Toxoplasma gondii</i>	<i>Plasmodium falciparum</i>
107	<i>Loxodonta cyclotis</i>	<i>Trichechus senegalensis</i>	<i>Odobenus rosmarus</i>
108	<i>Upupa epops</i>	<i>Trichoplax adhaerens</i>	<i>Solenodon cubanus</i>
109	<i>Pelvetia canaliculata</i>	<i>Ulva lactuca</i>	<i>Pyropia tenera</i>
110	<i>Pyropia tenera</i>	<i>Ulva lactuca</i>	<i>Palmaria palmata</i>
111	<i>Trentepohlia aurea</i>	<i>Ulva lactuca</i>	<i>Gelidium sesquipedale</i>
112	<i>Gynaephora groenlandica</i>	<i>Ursus arctos</i>	<i>Hypsibius dujardini</i>
113	<i>Lepisma saccharina</i>	<i>Vespula pensylvanica</i>	<i>Callinectes sapidus</i>
114	<i>Pteropus vampyrus</i>	<i>Vulpes zerda</i>	<i>Bassariscus astutus</i>
115	<i>Dawsonia superba</i>	<i>Welwitschia mirabilis</i>	<i>Tmesipteris elongata</i>
116	<i>Asparagus setaceus</i>	<i>Woodwardia areolata</i>	<i>Agave tequilana</i>
117	<i>Balaenoptera musculus</i>	<i>Physeter macrocephalus</i>	<i>Eschrichtius robustus</i>
118	<i>Orcinus orca</i>	<i>Phocoena phocaena</i>	<i>Eubalaena glacialis</i>

119	<i>Dioscorea mexicana</i>	<i>Grammatophyllum speciosum</i>	<i>Vanilla planifolia</i>
120	<i>Phyllostachys bambusoides</i>	<i>Juncus effusus</i>	<i>Lamarckia aurea</i>
121	<i>Brassica oleracea</i>	<i>Helianthus annuus</i>	<i>Lactuca sativa</i>
122	<i>Piper nigrum</i>	<i>Schinus molle</i>	<i>Capsicum chinense</i>