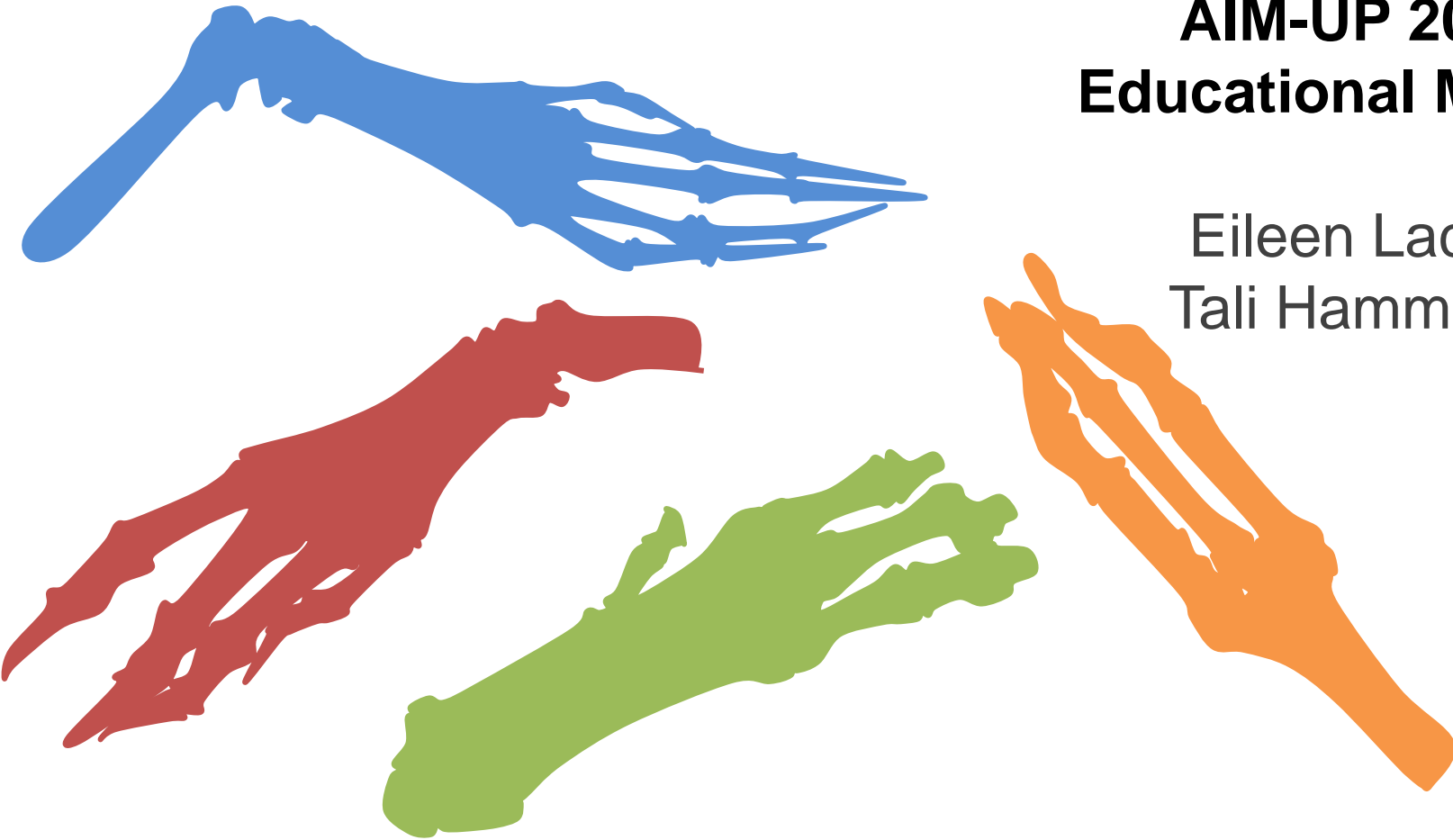


Descent with Modification: Losing It!

**AIM-UP 2014
Educational Module**

Eileen Lacey
Tali Hammond



Background

Use museum specimens of rodents with modified hind-limb digits to illustrate **adaptation**, **convergent evolution**, **functional morphology**, and **phylogenetic principles**



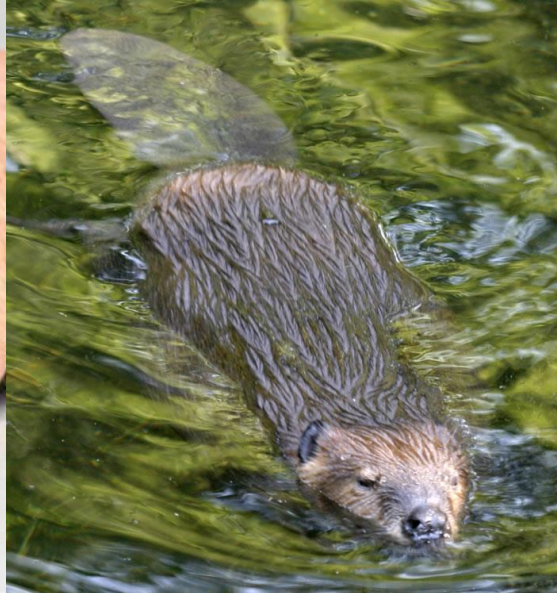
Background

Introduce students to
online resources

Make connections
between morphology,
genetics, evolution &
ecology/behavior

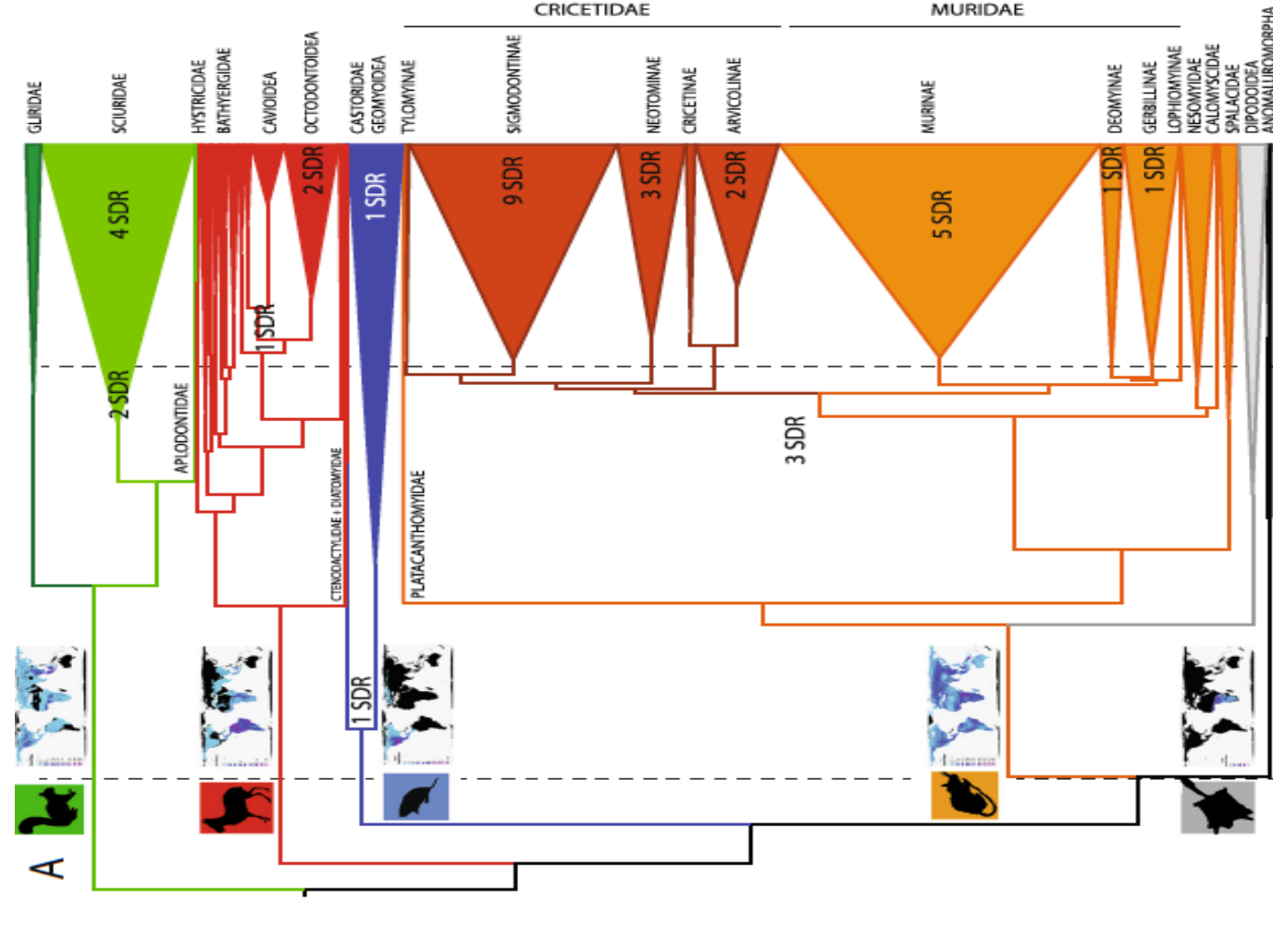


Rodents as a Case Study : Diversity



Rodents as a Case Study: Phylogenetics

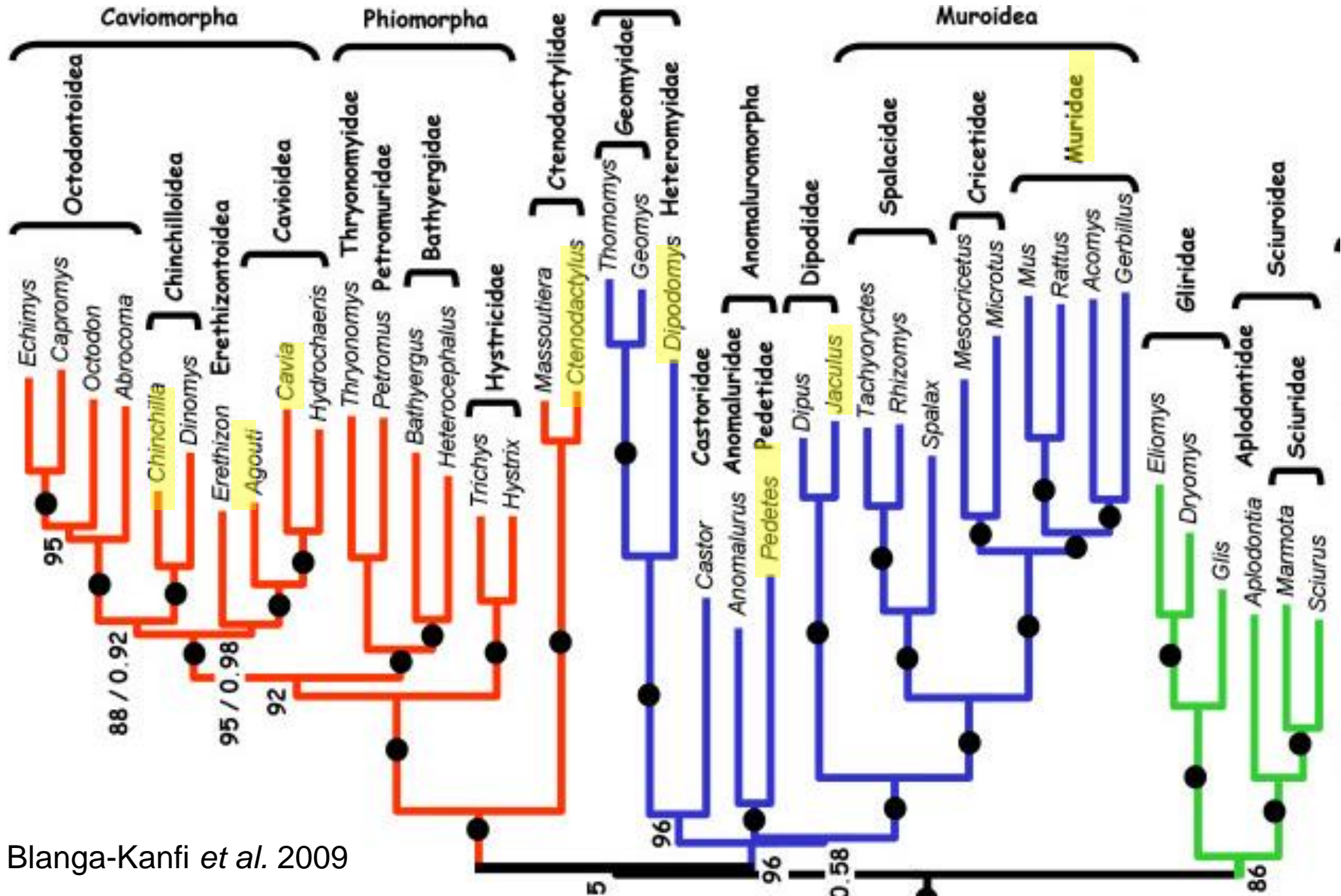
- Known phylogeny
- Available genetic data



Rodents as a Case Study: Digit Loss



Rodents as a Case Study: Digit Loss



The Activity

- Step 1: Record morphologic data from museum specimens
- Step 2: Make a morphology-based phylogeny
- Step 3: Make a genetic phylogeny using GenBank data
- Step 4: Compare the ecology/behavior of focal species using GBIF & ADW.

Step 1: Data Collection

- Go to the collections (or photos) to survey the focal species & record data

Genus	5 digits	4 digits	3 digits
Chinchilla			
Dipodomys			
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Step 1: Data Collection

- Go to the collections (or photos) to survey the focal species & record data

Genus	5 digits	4 digits	3 digits
Chinchilla			
Dipodomys			
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Chinchilla



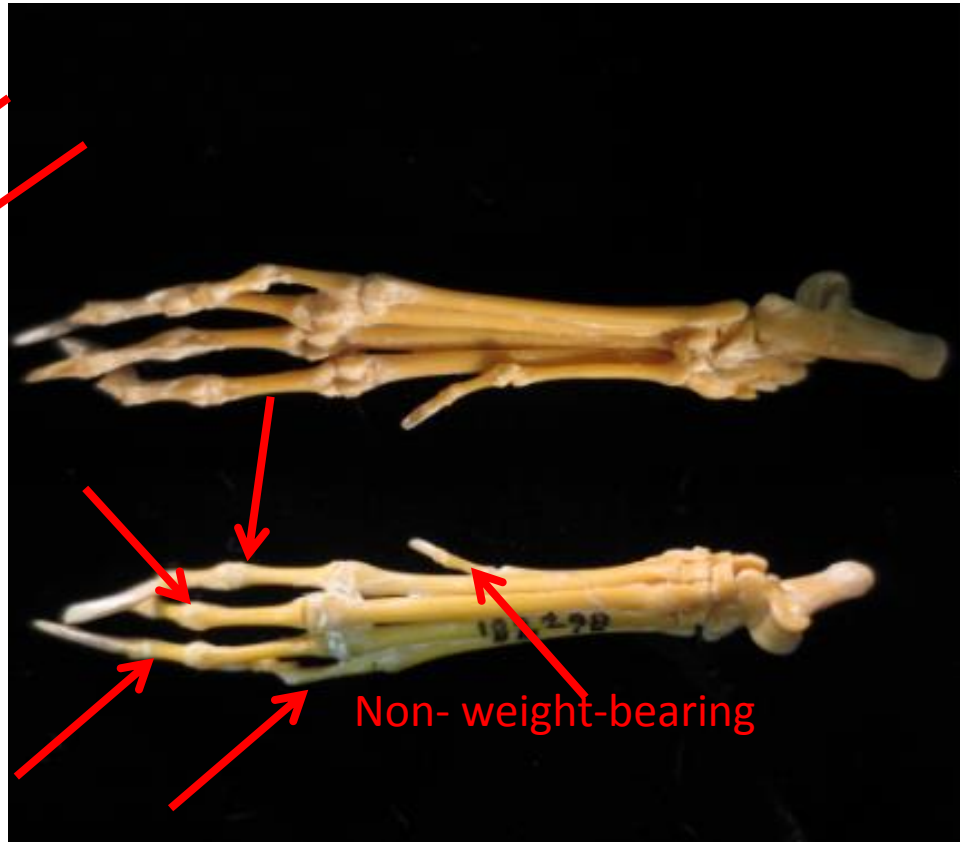
Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys			
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys			
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Dipodomys



Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys	0	1	0
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys	0	1	0
Jaculus			
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Jaculus



Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys	0	1	0
Jaculus	0	0	1
Notmoys			
Pedetes			
Dolichotis			
Dasyprocta			
Sciuridae			
Lepus			

Step 1: Data Collection

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys	0	1	0
Jaculus	0	0	1
Notmoys	0	1	0
Pedetes	0	1	0
Dolichotis	0	0	1
Dasyprocta	0	0	1
Sciuridae	1	0	0
Lepus	0	0	1

Step 2: Morphological Phylogeny

- Make a phylogeny based on the traits

Genus	5 digits	4 digits	3 digits
Chinchilla	0	0	1
Dipodomys	0	1	0
Jaculus	0	0	1
Notmoys	0	1	0
Pedetes	0	1	0
Dolichotis	0	0	1
Dasyprocta	0	0	1
Sciuridae	1	0	0
Lepus	0	0	1

Step 2: Morphological Phylogeny

- Make a phylogeny based on the traits

Genus	5 digits	4 digits	3 digits	Baculum	2 upper incisors	4 upper incisors
Chinchilla	0	0	1	1	1	0
Dipodomys	0	1	0	1	1	0
Jaculus	0	0	1	1	1	0
Notmoys	0	1	0	1	1	0
Pedetes	0	1	0	1	1	0
Dolichotis	0	0	1	1	1	0
Dasyprocta	0	0	1	1	1	0
Sciuridae	1	0	0	1	1	0
Lepus	0	0	1	0	1	1

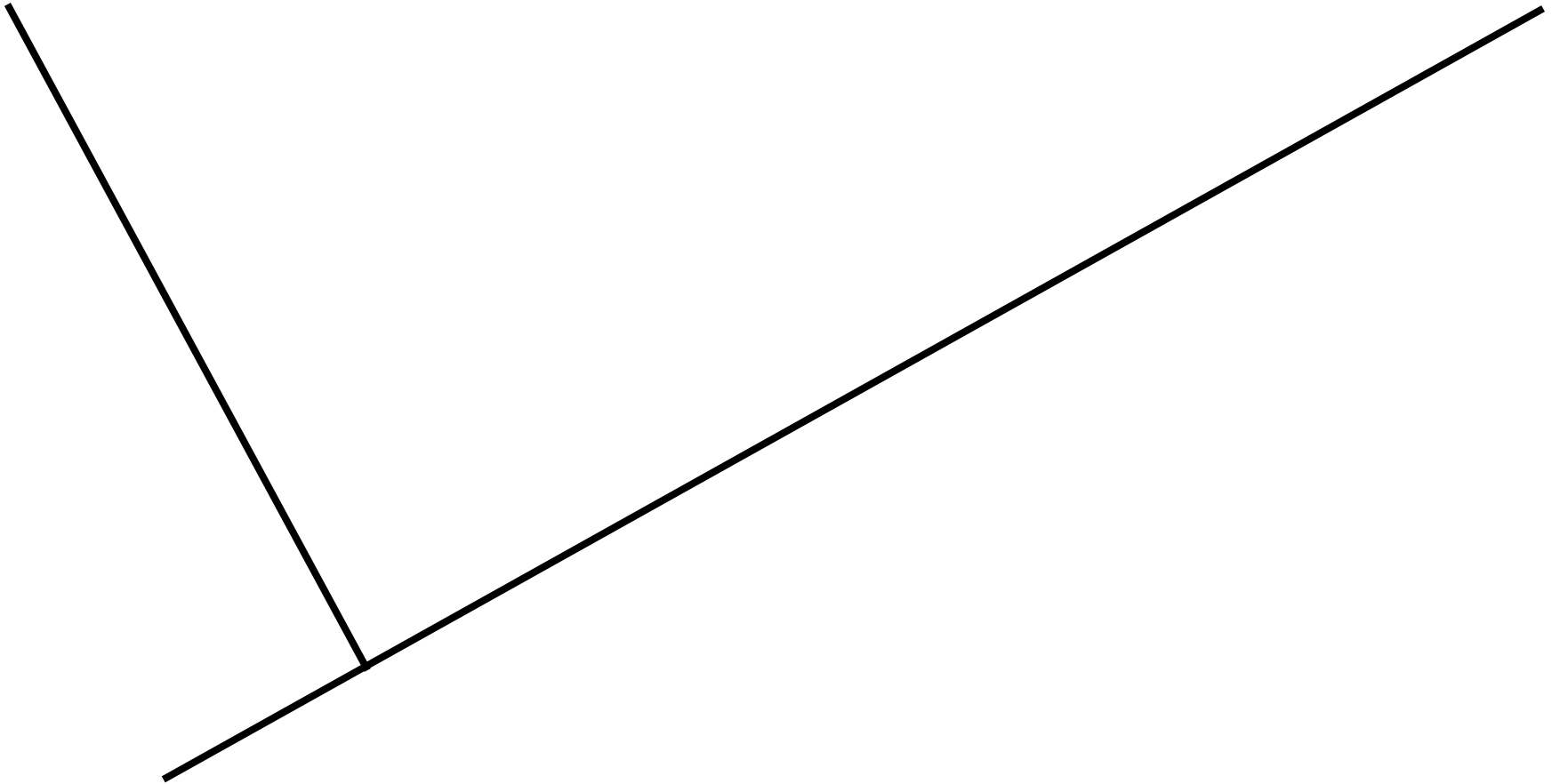
Clues about out-groups

Step 2: Morphological Phylogeny

Genus	5 digits	4 digits	3 digits	Baculum	2 upper incisors	4 upper incisors
Chinchilla	0	0	1	1	1	0
Dipodomys	0	1	0	1	1	0
Jaculus	0	0	1	1	1	0
Notmoys	0	1	0	1	1	0
Pedetes	0	1	0	1	1	0
Dolichotis	0	0	1	1	1	0
Dasyprocta	0	0	1	1	1	0
Sciuridae	1	0	0	1	1	0
Lepus	0	0	1	0	0	1

Step 2: Morphological Phylogeny

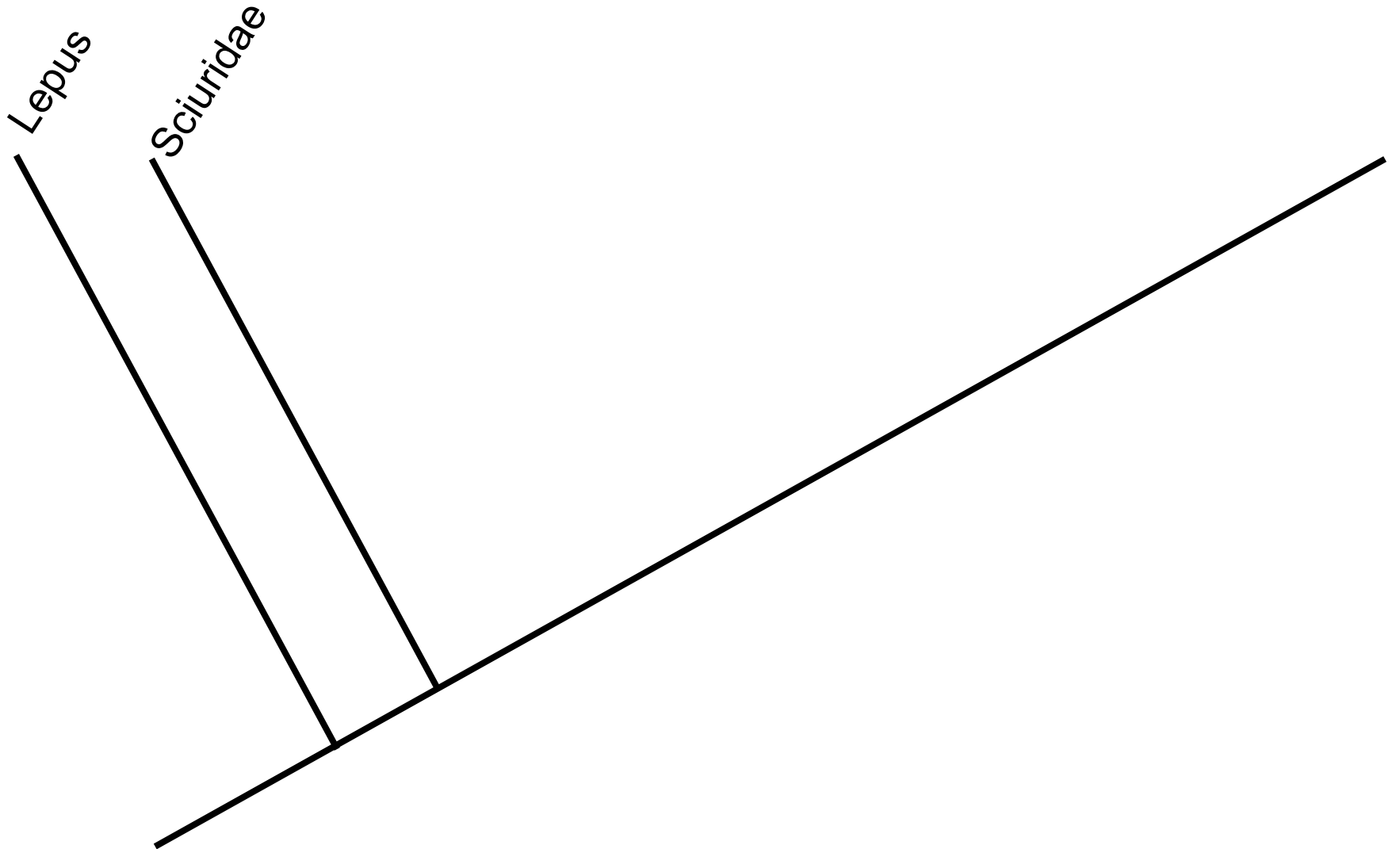
Lepus



Step 2: Morphological Phylogeny

Genus	5 digits	4 digits	3 digits	Baculum	2 upper incisors	4 upper incisors
Chinchilla	0	0	1	1	1	0
Dipodomys	0	1	0	1	1	0
Jaculus	0	0	1	1	1	0
Notmoys	0	1	0	1	1	0
Pedetes	0	1	0	1	1	0
Dolichotis	0	0	1	1	1	0
Dasyprocta	0	0	1	1	1	0
Sciuridae	1	0	0	1	1	0
Lepus	0	0	1	0	0	1

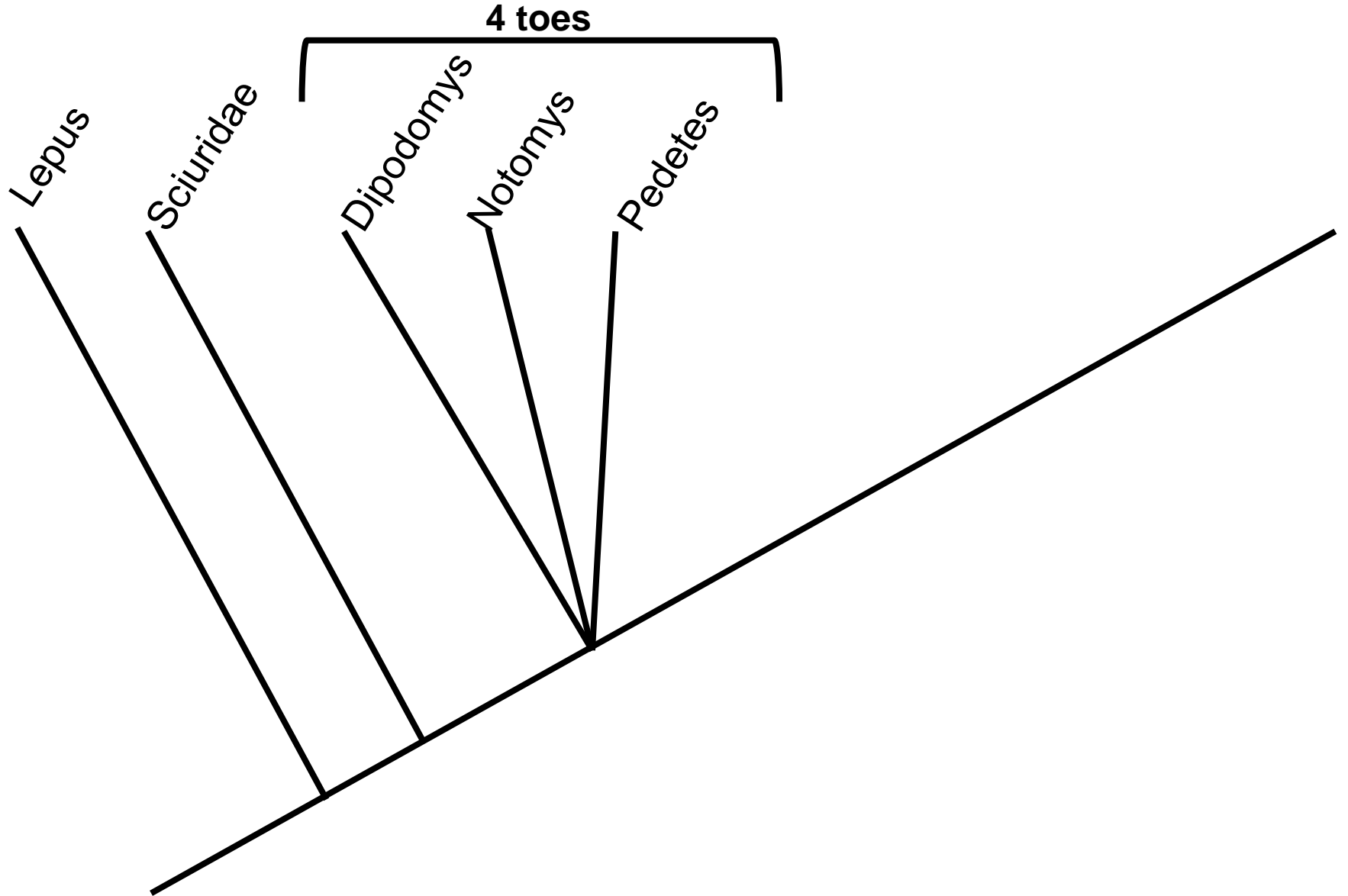
Step 2: Morphological Phylogeny



Step 2: Morphological Phylogeny

Genus	5 digits	4 digits	3 digits	Baculum	2 upper incisors	4 upper incisors
Chinchilla	0	0	1	1	1	0
Dipodomys	0	1	0	1	1	0
Jaculus	0	0	1	1	1	0
Notmoys	0	1	0	1	1	0
Pedetes	0	1	0	1	1	0
Dolichotis	0	0	1	1	1	0
Dasyprocta	0	0	1	1	1	0
Sciuridae	1	0	0	1	1	0
Lepus	0	0	1	0	0	1

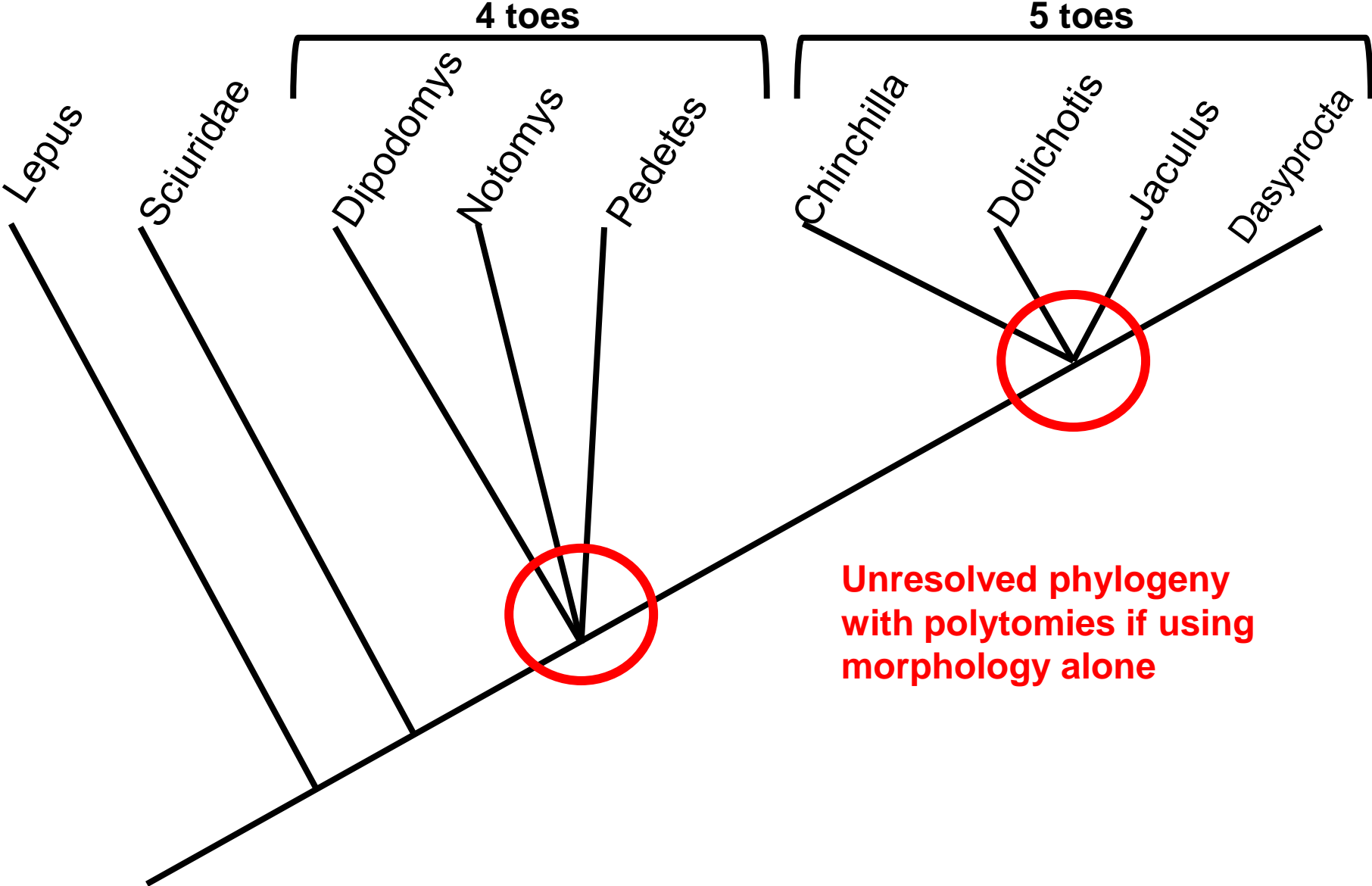
Step 2: Morphological Phylogeny



Step 2: Morphological Phylogeny

Genus	5 digits	4 digits	3 digits	Baculum	2 upper incisors	4 upper incisors
Chinchilla	0	0	1	1	1	0
Dipodomys	0	1	0	1	1	0
Jaculus	0	0	1	1	1	0
Notmoys	0	1	0	1	1	0
Pedetes	0	1	0	1	1	0
Dolichotis	0	0	1	1	1	0
Dasyprocta	0	0	1	1	1	0
Sciuridae	1	0	0	1	1	0
Lepus	0	0	1	0	0	1

Step 2: Morphological Phylogeny



Step 3: Genetic Phylogeny

- Make a phylogeny using GenBank & Geneious. Compare to morphological phylogeny and to advanced, updated nuclear phylogeny

Step 3: GenBank

NCBI Resources ▾ How To ▾ Sign in to NCBI

Nucleotide [Limits](#) [Advanced](#) [Help](#)

Display Settings: ▾ FASTA

Send: ▾

Clipboard: [1 item](#)

Chinchilla brevicaudata voucher LCM 2426 cytochrome b (cytb) gene, partial cds; mitochondrial

GenBank: AF464758.1

[GenBank](#) [Graphics](#)

```
>gi|27462987|gb|AF464758.1| Chinchilla brevicaudata voucher LCM 2426 cytochrome b
(cytb) gene, partial cds; mitochondrial
ATGACCAATATACGTAATACACACCCCTACTCAAAATAATCAACCACCTCGTTCATCGACCTACCAACCC
CATCCAACATCTCAGCCTGATGAAATTCGGCTCTTTATTGGGTGTATGCCTAATTTTACAAATTATCAC
CGGATTATTCCTAGCGATACACTATACCGGGACACCACCTACGGCCTTCTCATCAGTCACCCACATCTGC
CGAGACGTAACACTACGGCTGGCTAATCCGATACCTCCATGCTAACGGAGCATCTATATTCTTTATCTTCC
TTTACTTCCACGTAGGACGTGGAATTTATTACGGATCATATCTATTCTAGAAACCTGAAACATCGGAGT
CATCCTACTGTTAACGGTCATAGCAACAGCCTTCATAGGATACGCTCTGCCATGAGGACAGATATCATTC
TGAGGCGCTACAGTAATCACAAACCTCCTCAGCTATCCCTTATATCGGACCTACTCTCGTAGAATGAA
TTTGAGGCGGATTCGAGTAGACAAAGCAACCCTGACTCGATTCTTTGCATTCCACTTCATCCTCCATT
```

Change region shown ▾

Customize view ▾

Analyze this sequence ▴

[Run BLAST](#)

[Pick Primers](#)

[Highlight Sequence Features](#)

[Find in this Sequence](#)

Related information ▴

[Related Sequences](#)

[Protein](#)

[Taxonomy](#)

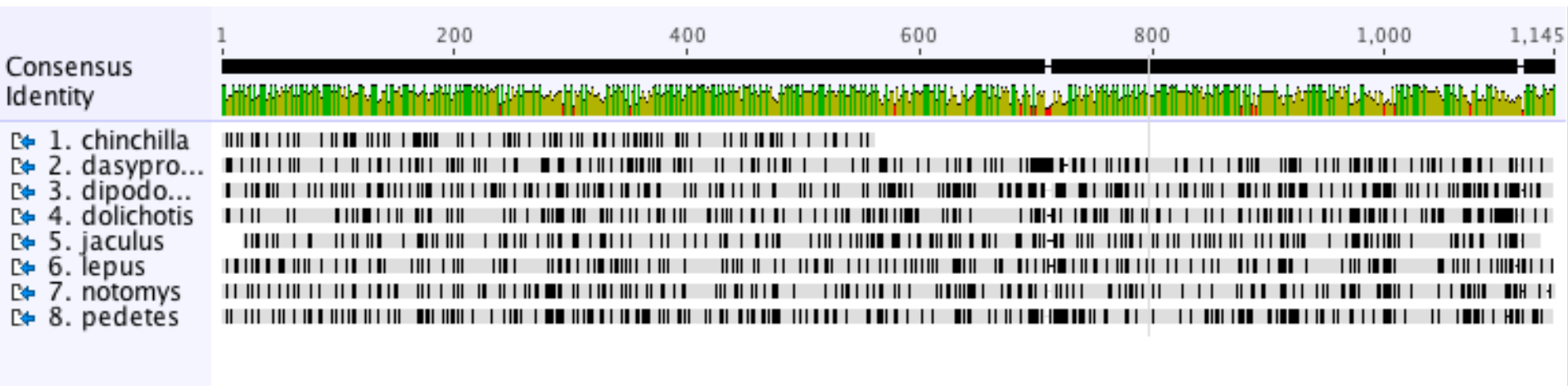
Step 3: GenBank

```
cytB.txt
>gi|289707227|gb|GU433441.1| Jaculus jaculus voucher 256 cytochrome b gene, partial cds; mitochondrial
ACTCACCTCTTATAAAAAATCGTCAAGGAATCATTTCATTGACCTACCCACCCCATCTAATATCTCAGCAT
GATGAACTTCGGCTCCCTACTAGGTATGTGCCTAATCATCCAAATTGCCACAGGACTATTCTAGCCAT
ACACTACACATCCGACACCACAACCTGCCTTCTCATCCGTCGCCATATCTGCCGAGATGAAAACACGGA
TGACTAATCCGCTACCTCCACGCCAATGGGCTCAATATTCTTATCTGCTATTCTACATGTAGGAC
GAGGCTCTACTACGGATCCTACACATTTATCGAACTTGAACATCGGAATCCTTCTCTATTTGCAGT
CATAGCCACAGCCTTTATAGGCTATGTTCTCCATGAGGCCAAATATCCTTCTGAGGCGCCACAGTCATT
ACAAACCTCTATCAGCTATTCCTACATTGGAACACCCTCGTGAATGAATCTGAGGCGGATTCTCGG
TAGATAAAGCTACACTAACCCGGTCTTTCGCCTTCATTTTCATCTTCTTTCATCGAAGCAGCCCTGGC
AGTAGTTCACCTCTATTCTTACACGAACTGGCTCCAACAACCAATTTGGACTAAACTCTGACGCAGAC
AAAAATCCCTTTCACCTTACTACACAATCAAAGACGCCCTAGGATTTTTCTAATATCTAGTTCTCC
TTTTCTAGTCTCTTTCGCCGGACATACTAGGAGACCCGACAATTACATACCCGCAAAACCCCTTAA
TACACCACCCATATCAAACCTGAATGGTACTTCTATTTGCCTACGCTATTCTCCGATCTATCCCTAAC
AAACTCGGTGGTGTAGTAGCCCTAGTCTTATCCATCCTAATCTAGCTATTGTCCTTCTACACAAC
CAAAACAACGCAGCATAATTTCCGACCCATCAGTCAATGCATGTACTGACTTCTCGTAGCAGACCTCT
TACTCTACCTGAATTGGAGGTCAACCAAGTGAACACCCATTTATCATCTTGGCCAAATCGCATCCATC
CTATACTTCATAATCATCTAATCCTTATACCTCTATCAAGCATACTAGAAAACAAAATC

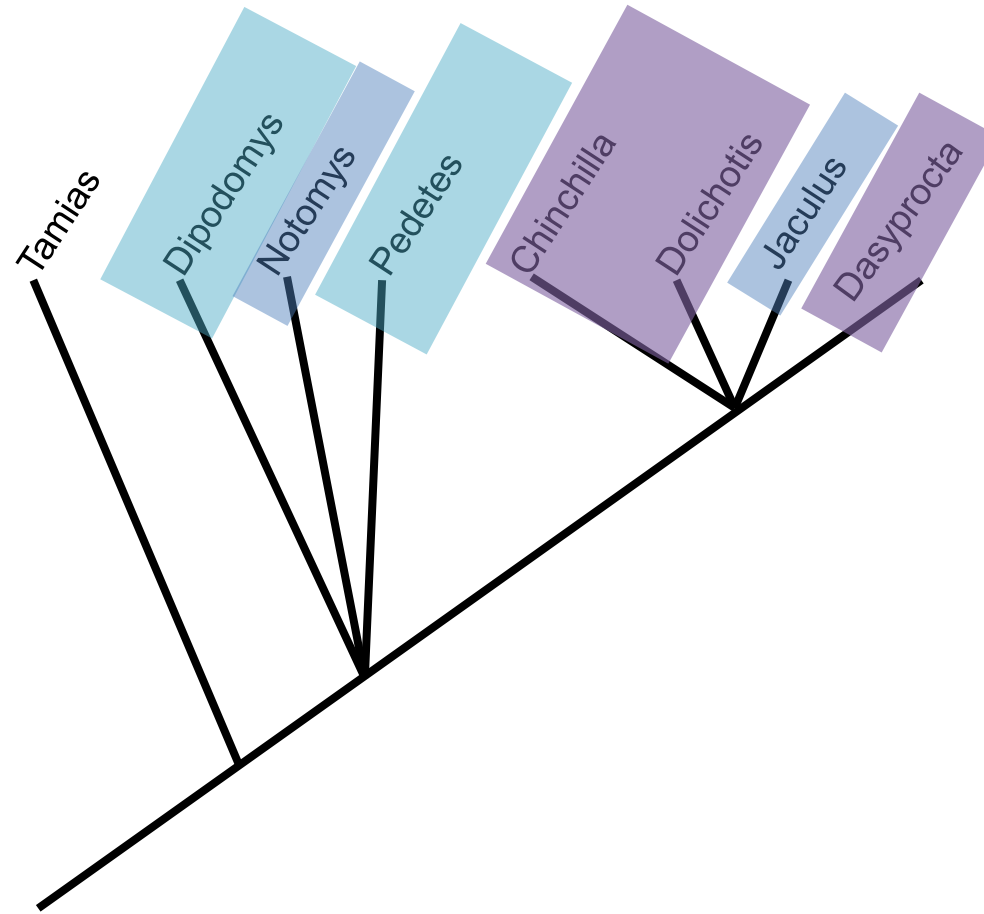
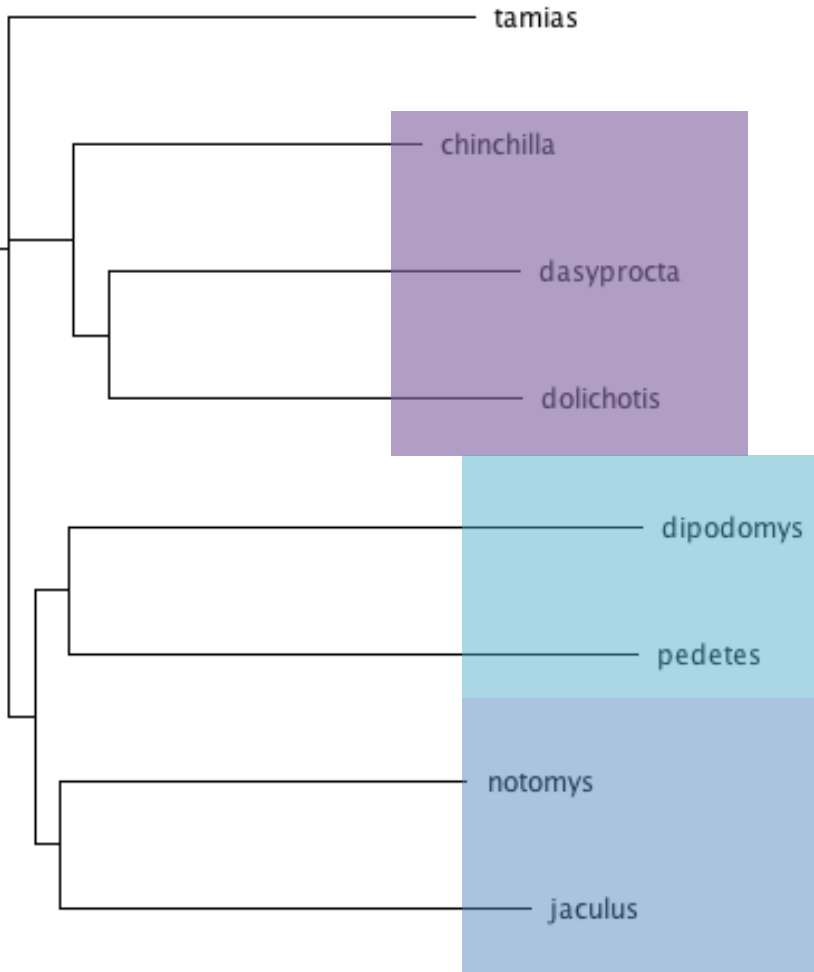
>gi|27462987|gb|AF464758.1| Chinchilla brevicaudata voucher LCM 2426 cytochrome b (cytb) gene, partial cds; mitochondrial
ATGACCAATATACGTAATACACACCCCTACTCAAATAATCAAACACTCGTTTCATCGACTACCAACCC
CATCCAACATCTCAGCCTGATGAAATTTTCGGCTCTTATTGGGTGTATGCCTAATTTTACAAATATCAC
CGGATTATTCCTAGCGATACATATACCCGGACACCACACGCGCTTCTCATCAGTACCCACATCTGC
CGAGACGTAAACTACGGCTGGCTAATCCGATACCTCCATGCTAACGGAGCATCTATATTCTTTATCTTCC
TTTACTTCCAGTAGGACGTGGAATTTATTACGGATCATATCTATTCTAGAAACCTGAAACATCGGAGT
CATCTACTGTTAACGGTCATAGCAACAGCCTTCATAGGATACGTCCTGACATGAGGACAGATATCATT
TGAGGCGCTACAGTAATCACAACCTCCTCTCAGCTATCCCTTATATCGGACCTACTCTGTAAGATGAA
TTTGAGGCGGATTCGAGTAGACAAAGCAACCTGACTCGATTCTTGCATTCCAATTATCCTCCCAT

>gi|62953019|gb|AY926368.1| Dipodomys californicus isolate LVT 2037 cytochrome b (cytb) gene, complete cds; mitochondrial
ATGACAATCATACGAAAAACCCACCCACTGATAAAAAATAGTAAATCACGCATTCAATGACCTTCCACCC
CATCAAACATTTAGGATGATGAAATTTGGCTCACTCTAGGAATATGCCTAATTTACAAATCGCCTC
AGGCTATTTCTAGCCATACATTACACACCAGATACCCTCACAGCATTCTGATCAGTCGCCATATCTGC
CGAGACGTAAACTACGGTTGANTTATTCGCTACATACACGGTAATGGAGGCTCACTTTTCTTCTATCTGCC
TTTACTTTCACATTGGCCGAGGAATCTACTATGGCTCATACTCTTACACAGAACTTGAACATTTGGTAT
TATTCTCCTTTTTCTTACTATAGCAACCGCCTTCATAGGCTATGTTCTTCCATGGGCAAAATATCATT
TGAGGAGCAACAGTAATTACTAACCTACTATCAGCTATCCGTCATCGGAACAGATCTAGTAGAATGAA
TCTGAGGAGCTTCTCTGTAGACAAAGCTACCCTAAACCGGTTCTTTCGATTCCAATTATTCTACCATT
TATCATTGCTGCCACAGTATAGTCCATCTACTTTTCTCCACGAAACAGGATCAAACAATCCACTAGGC
ATTCCATCCGATTGCATAAAAATCCATTCCACCCATATTATACAACTAAAGACTTTTTAGGAGTTATCC
```

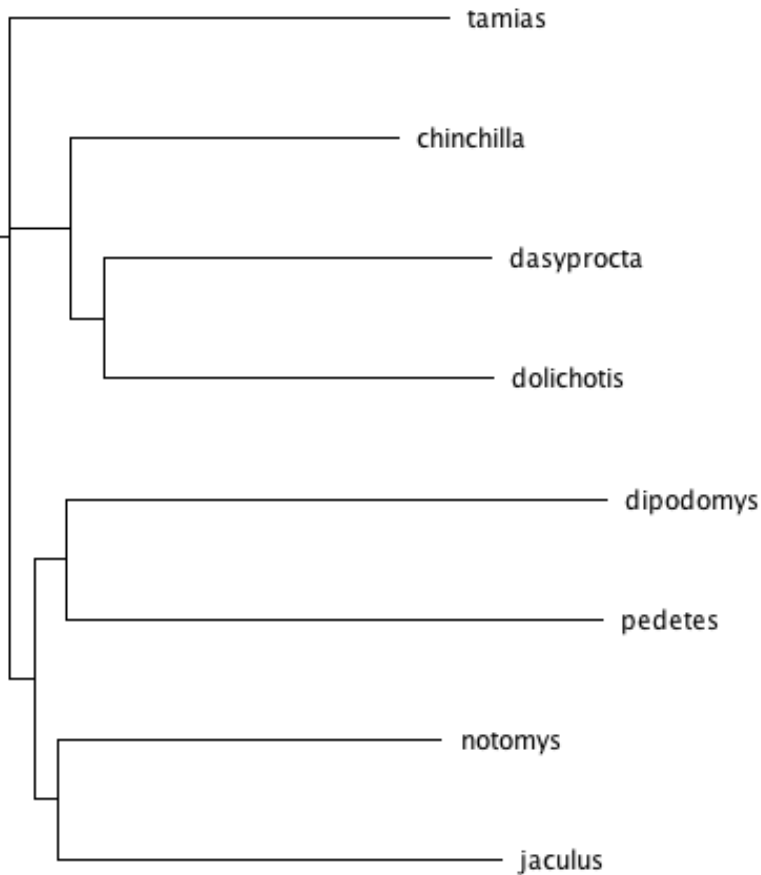

Step 3: Geneious Multiple Alignment



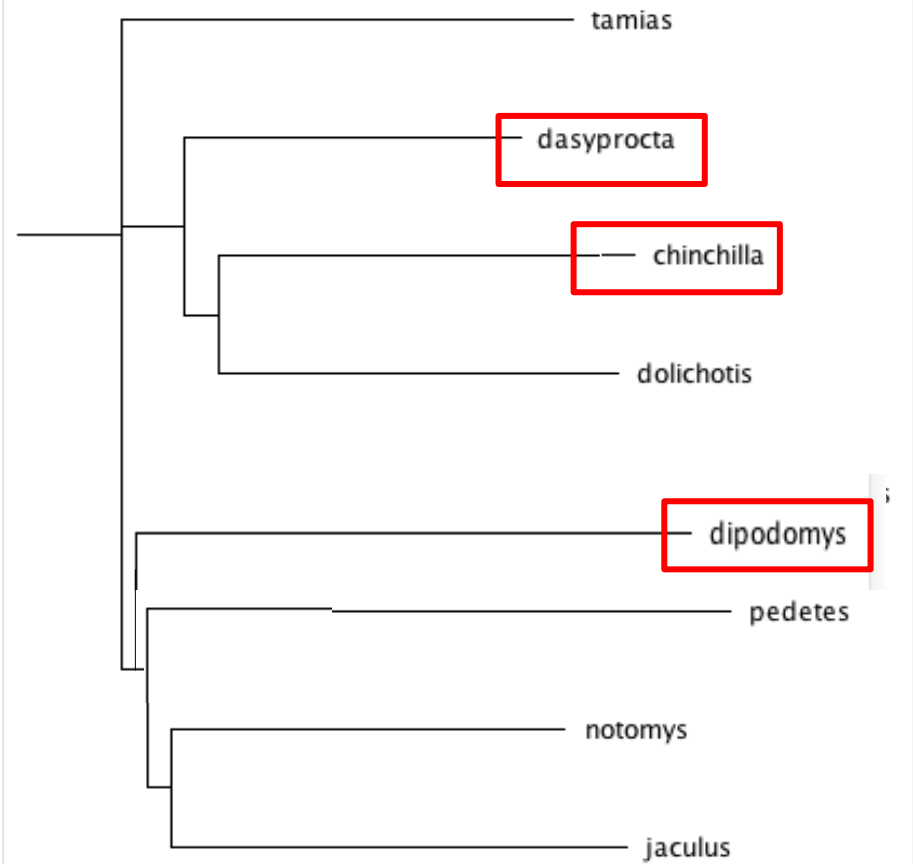
Step 3: Geneious Tree



Step 3: Nuclear & mt Tree

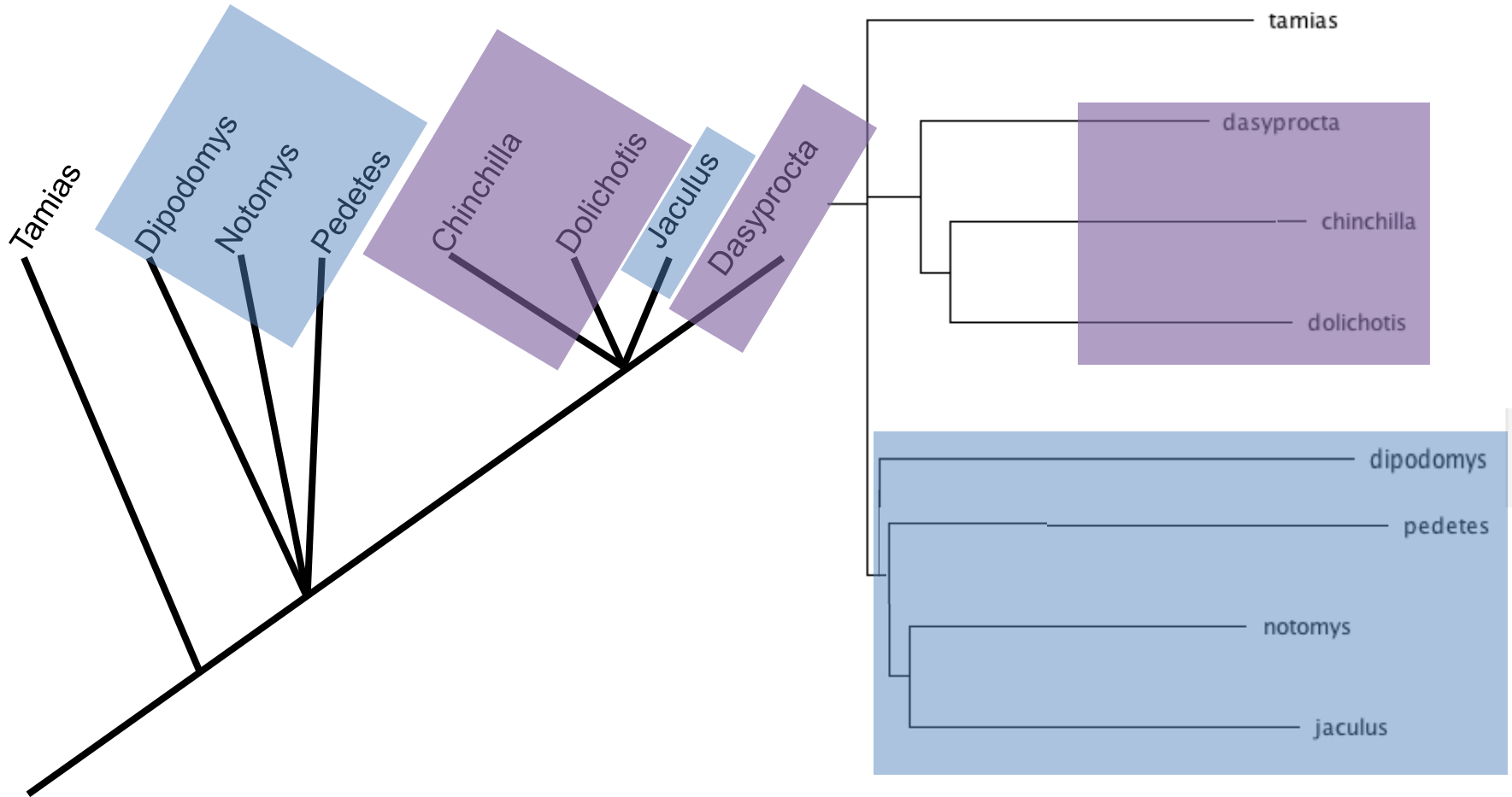


Genbank cytochrome-B



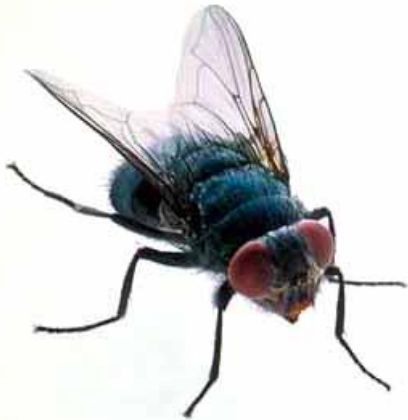
11 mt and nuclear genes ML phylogeny (Fabre *et al.* 2012)

Step 3: Nuclear & mt Tree



Step 3: Address Convergence

- Multiple origins
- Why would this trait have evolved multiple times – how is it adaptive?



Step 4: Ecological Connections

- How does toe loss make these animals better adapted to their habitats?
- What ecological/behavioral traits may explain digit loss in these genera?

Step 4: GBIF

GBIF.ORG
Free and open access to biodiversity data

Data · News · Community · About

Jaculus jaculus (Linnaeus, 1758)

Species in GBIF Backbone Taxonomy

1,576 Occurrences | 0 Intraspecies

[View occurrences](#)

Animalia · Chordata · Mammalia · Rodentia · Dipodidae · Jaculus

Information

Overview

FULL NAME	TAXONOMIC STATUS
Jaculus jaculus (Linnaeus, 1758)	Accepted species
COMMON NAMES	ACCORDING TO

VIEW RECORDS
All 900 | In viewable area

DISTRIBUTIONS
Text based [distributions](#) present in some sources.

Step 4: GBIF

GBIF.ORG
Free and open access to biodiversity data

Data · News · Community · About

Pedetes Illiger, 1811

Genus in GBIF Backbone Taxonomy

Animalia · Chordata · Mammalia · Rodentia · Pedetidae


1,370 Occurrences | 2 Species

[View occurrences](#)

Information

Overview

FULL NAME	TAXONOMIC STATUS
Pedetes Illiger, 1811	Accepted genus
COMMON NAMES	ACCORDING TO
· Springhares eng ↗	The Catalogue of Life, 3rd January 2011
SYNONYMS	PUBLISHED IN
· <i>Gerbua</i> Cuvier, 1825	Prod., 81



EXTERNAL LINKS

- [Encyclopedia of Life](#)
- [Catalogue of Life](#)
- [Biodiversity Heritage Library](#)

GBIF ID [2439826](#)

Georeferenced data

VIEW RECORDS

All 449 | [In viewable area](#)

Step 4: Animal Diversity Web

Animal Diversity Web



University of Michigan
MUSEUM OF ZOOLOGY



Jaculus jaculus lives in **desert and semi-desert** areas that can be sandy or stony. They can also be found in less numbers in rocky valleys and meadows. ("Walker's Mammals of the World", 1997)

Habitat Regions: temperate ; terrestrial

Terrestrial Biomes: desert or dune

Jaculus jaculus can be found in central Asia, North Africa and Arabia in

bottom. Jerboas **move by hopping along the terrain** with their huge hind legs. One leap can be several meters in length. They

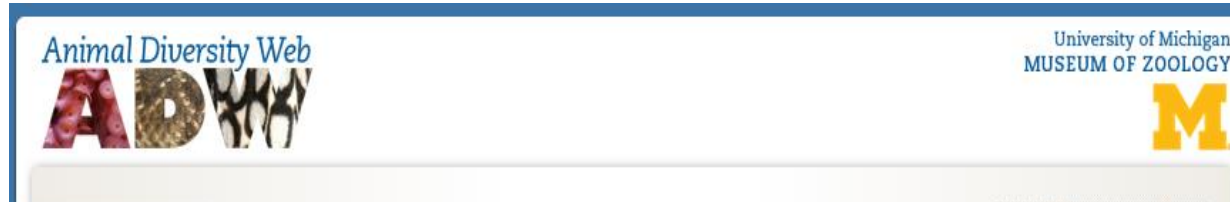
Jaculus jaculus lives in desert and semi-desert areas that can be sandy or stony. They can also be found in less numbers in rocky valleys and meadows. ("Walker's Mammals of the World", 1997)

Habitat Regions: temperate ; terrestrial

Terrestrial Biomes: desert or dune

Subphylum
Vertebrata
vertebrates
Class
Mammalia
mammals

Step 4: Animal Diversity Web



Habitat

Springhares live in areas with sandy, dry soil. They also can be found in areas of cattle grazing and cultivation of crops such as wheat, oats, and barley. They dig underground tunnels and live in them.

Terrestrial Biomes: desert or dune ; savanna or grassland

they come out at night. The springhare jumps like a kangaroo on its hind legs, retreating to its burrow when frightened.

Biogeographic Regions: [ethiopian](#) ([native](#))

Habitat

Springhares live in areas with sandy, dry soil. They also can be found in areas of cattle grazing and cultivation of crops such as wheat, oats, and barley. They dig underground tunnels and live in them.

Terrestrial Biomes: [desert or dune](#) ; [savanna or grassland](#)

Phylum
Chordata
chordates
Subphylum
Vertebrata
vertebrates
Class
Mammalia
mammals

Step 4: Ecological Connections

Genus	Habitat	Place	Movement
Chinchilla	grassland/savanna mountains	W. S.America	saltatorial
Dipodomys	desert/dune grassland/savanna chaparral	W. N.America	saltatorial
Jaculus	desert/dune	N. Africa	saltatorial
Notomys	desert/dune grassland/savanna	Australia	saltatorial
Pedetes	desert/dune grassland/savanna	S. Africa	saltatorial
Dolichotis	desert/dune grassland/savanna scrub forest	S.America	cursorial/saltatorial
Dasyprocta	various	C./S. America	cursorial/saltatorial

Step 4: Ecological Connections

- Functional morphology: toe loss for better running/jumping ? These motions adaptive in desert grasslands?



Future Directions

- Other groups with digit modification
- Genetics of digit modification
- Connection to human health
- Biomechanics

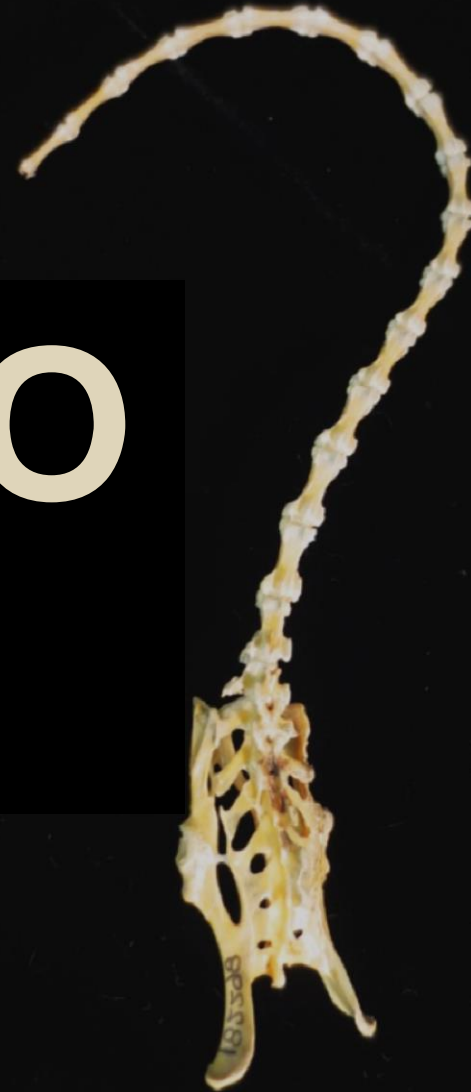


Museums & Education

-



QUESTIONS



END

TTH background info/to do list

- Kim Cooper (HU) toe loss
- Go to collection, select subset of rodents with toe-loss (include some homoplasy, also an outgroup?), take photos of feet (or use online photos?). Be selective
- Students will use photos (or actual specimens). They will look at which animals have lost digits, which digits are lost, etc. Using this information only they will make a phylogeny
- Then they will go to genbank and use cytochrome B sequences to find out the true phylogeny. Compare the 2 phylogenies, learn about homoplasy
- Then they can go to GBIF or animal diversity web to find out about where these animals live (mainly desert) and form hypotheses about this adaptation's functional role
- Make a final evo-devo link? A human impacts link?

SUBORDER	INFRAORDER	FAMILY	SUBFAMILY	GENUS	SPECIES	COMMON NAME	# TOES
HYSTRICOMORPHA		Ctenodactylidae		Ctenodactylus		Gundi	4
HYSTRICOMORPHA		Pedetidae		Pedetes		Spring hare	4
HYSTRICOMORPHA	HYSTRICOGNATHI	Chinchillidae		Chinchilla		Chinchilla	3
HYSTRICOMORPHA	HYSTRICOGNATHI	Dasyproctidae		Dasyprocta		Agouti	3
HYSTRICOMORPHA	HYSTRICOGNATHI	Caviidae		Dolichotis		Patagonian hare	3
MYOMORPHA		Muridae	Murinae	Notomys		Hopping mice	
MYOMORPHA		Dipodidae		Allactaga Jaculus Zapus Napeozapus	hotsoni, elater jaculus, blanfordi	Jerboa Jerboa Jumping mice Jumping mice	5 (2 sm) 3 5 5
CASTORIMORPHA		Heteromyidae	Dipodomysinae	Dipodomys Microdipodops		Kangaroo rats Kangaroo mice	4-5 ?
CASTORIMORPHA		Heteromyidae	Heteromyinae	Heteromys Liomys		Spiny pocket mice	5?
CASTORIMORPHA		Heteromyidae	Peroognathina	Chaetodipus		Pocket mice	5?

FINAL

