

Detailed Results

3.1 Tanglegram Comparisons

3.1.2. Ordinal Level, Detailed

The *Zan* tree included only a single species from Superorder Xenarthra, *Dasypus novemcinctus* (nine-banded armadillo), and only a single species from the Order Pilosa, *Choloepus didactylus* (Linnaeus' two-toed sloth). Within Afrotheria, the *Zan* tree's topology depicted the Order Afrosoricida in part (tenrec clade) as basal to the remaining Afrotheria Orders (Figs. 1 and 3). The Order Tubulidentata formed the next basal-most group with the remaining Orders placed into two clades; the first composed of Order Afrosoricida in part (golden mole clade) as a sister taxon with Order Hyracoidea (hyraxes) and the second composed of Order Sirenia (manatees) as a sister taxon with Order Proboscidea (elephants). The *Zan* tree did not depict the Traditional Clade Paenungulata which is comprised of the Orders Hyracoidea, Sirenia, and Proboscidea.

Following the divergence of Afrotheria and Xenarthra in the *Zan* tree (Figs. 1 and 4), a divergence event occurred between Superorder Laurasiatheria (Orders Eulipotyphla-shrews, true moles, and hedgehogs; Pholidota-pangolins; Carnivora-carnivores; Cetartiodactyla-even-toed ungulates; Perissodactyla-odd-toed ungulates; and Chiroptera-bats) and Superorder Euarchontoglires containing the remaining placental mammals (Orders Scandentia-treeshrews; Dermoptera-flying lemurs; Primates-primates; Lagomorpha-rabbits and pikas; and Rodentia-rodents). Within Laurasiatheria, Eulipotyphla formed the basal-most group, with the remaining taxa in Traditional Clade Scrotifera, including Orders Pholidota, Carnivora, Cetartiodactyla, Chiroptera, and Perissodactyla, forming a monophyletic group.

3.1.3. Intra-Ordinal Level, Detailed

Order Chiroptera-- In the *Zan* tree, (Figs. 1 and 5), the seven families comprising the Order Chiroptera, formed two clades. The first clade included the Suporder Yinpterochiroptera (Families Hipposideridae-Old World leaf-nosed bats, Rhinolophidae-horseshoe bats, and Pteropodidae megabats), whereas the second clade included the Suborder Yangochiroptera (Families Phyllostomidae-leaf-nosed bats, Molossidae-free-tailed bats, Miniopteridae-long-winged bats, and Vespertilionidae-vesper bats). Within the Yinpterochiroptera, Pteropodidae was placed as the basal most taxon with Hipposideridae and Rhinolophidae forming a sister relationship. Within the Yangochiroptera, Phyllostomidae was placed as the basal-most taxon, followed by Molossidae, with Miniopteridae and Vespertilionidae forming a sister relationship.

The nineteen bat species included in this study all grouped within the genera from their respective families (Figs. 1 and 6). A one species representative of the Family Hipposideridae was available; consequently, *Hipposideros* (great roundleaf bat) grouped as basal to both species of *Rhinolophidae*, *R. ferrumequinum* (greater horseshoe bat) and *R. sinicus* (Chinese rufous horseshoe bat). Within the Pteropodidae, *Rousettus* (Egyptian fruit bat) was placed as basal to all three *Pteropus* spp: *Pteropus alecto* (black flying fox), *Pteropus vampyrus* (large flying fox), and *Pteropus giganteus* (Indian flying fox). A one species representative of the Family Molossidae was available; consequently, *Molossus* (Mexican free-tailed bat) grouped as basal to the remaining members of Yangochiroptera. The next basal most group was the single species of the Family Miniopteridae, *Miniopterus* (natal long-fingered bat) followed by the Vespertilionidae. Within Vespertilionidae, a clade of *Pipistrellus* (Kuhl's pipistrelle) and *Eptesicus* (big brown bat) shared a sister relationship and

all *Myotis* spp formed a clade: *Myotis myotis* (greater mouse-eared bat), *Myotis davidii* (David's Myotis), *Myotis brandtii* (Brandt's bat), and *Myotis lucifugus* (little brown bat).

Order Cetartiodactyla-- The Cetartiodactyla (Figs. 1 and 7) comprised ten families, with Camelidae (alpacas and camels) as the basal-most Family within Suborder Tylopoda. The next divergence led to Suidae (pigs and relatives) within Suborder Suina separating from the remaining members of the Cetartiodactyla: one large cohort, Suborder Ruminantia, including the terrestrial families Cervidae (hoofed ungulates) and Bovidae (cloven-hoofed ungulates), and another Suborder Whippomorpha, including the aquatic families Balaenopteridae (rorquals), Physeteridae (sperm whale), Lipotidae (river dolphins), Delphinidae (dolphins and orcas), Phocoenidae (porpoises), and Monodontidae (beluga whale and narwhal). Within the aquatic group, called Infraorder Cetacea, Parvorders Mysteceti and Odontoceti were sister groups, with the Balaenopteridae placed basally, followed by Physeteridae, then Lipotidae, Delphinidae, Phocoenidae, and Monodontidae, with Delphinidae basal to a clade containing the Phocoenidae and Monodontidae. For the Cetartiodactyla Family tree, the *Zan* and Supertree were in topological agreement.

Twenty-nine species in Cetartiodactyla all clustered within genera from their respective families (Figs. 1 and 8). Within the terrestrial group, the Camelidae was the basal-most taxon and consisted of *Vicugna* (alpaca), and the three *Camelus* spp.: *Camelus ferus* (feral camel), *Camelus bactrianus* (Bactrian camel), and *Camelus dromedarius* (dromedary camel). The next basal-most group included the Suidae, *Sus* (domestic pig) and *Phacochoeros* (warthog), and then the Cervidae which included *Odocoileus* (white-tailed deer) and the two *Cervus* spp., *Cervus elaphus* (red deer) and *Cervus canadensis* (elk). The final terrestrial Family included the Bovidae, which encompassed the species *Oryx* (scimitar oryx), *Capra* (domestic goat), *Ovis* (domestic sheep), *Bubalus* (water buffalo), *Bison* (buffalo), and the four *Bos* spp.: *B. grunniens* (yak), *B. taurus* (cow), *B. indicus* (zebu), and *B. hybrid* (zebu x cow). Within the aquatic group, the Balaenopteridae was the basal-most group which consisted of two *Balaenoptera* spp., *Balaenoptera musculus* and *Balaenoptera acutorostrata*, followed by the Physeteridae which consisted of one species, *Physeter* (sperm whale). The next divergence event led to the Lipotidae which consisted of one species, *Lipotes* (Yangtze River dolphin), followed by a clade containing four species within the Delphinidae: *Lagenorhynchus* (Pacific white-sided dolphin), *Orcinus* (killer whale), *Tursiops* (bottlenose dolphin), and the Globicephala (long-finned pilot whale). *Lagenorhynchus* was the basal-most species of the Delphinidae, followed by *Orcinus*, and then *Tursiops* and Globicephala formed a sister relationship.

Order Carnivora--The Carnivora comprised nine families (Figs. 1 and 9) with members of the Infraorder Canoidea (Family Canidae- dogs and relatives) as the basal-most group. A divergence event followed giving rise to two clades, one of which included members of the Suborders Feloidea (Family Felidae- cats and relatives) and Viverroidea (Family Hyaenidae- hyaenas and Family Herpestidae- mongoose and meerkats) and the other clade included members of the Infraorder Arctoidea (Families Mustelidae-otters and weasels, Ursidae-bears and pandas, Phocidae-earless seals, Otariidae-eared seals, and Odobenidae-walruses). Within the Feloidea and Viverroidea, the Felidae was the basal-most group with Hyaenidae and Herpestidae grouping as sister taxa. Within the Arctoidea, a divergence event occurred with one clade giving rise to the Mustelidae and Ursidae as sister taxa and another clade including the Phocidae, Odobenidae, and Otariidae, with the Phocidae as the basal-most taxon.

The Carnivora comprised 34 species, all of which grouped with genera in their respective families (Figs. 1 and 10). Within Canidae, *Canis familiaris* (domestic dog) and *Canis familiaris dingo* (dingo) formed a sister relationship along with *Vulpes velox* (red fox) and *Vulpes lagopus* (arctic

fox) which also formed a sister relationship. In the Mustelidae, Clade A, *Meles* (European badger) was the basal-most taxon, followed by *Mustela* (domestic ferret), *Neovison* (American mink), and *Enhydra* (Northern sea otter) and *Lontra* (North American river otter) forming a sister relationship. Within the Ursidae, Clade B, *Ailuropoda* (Giant panda) was placed as the basal-most taxon to two clades of *Ursus* species: one clade of *Ursus americanus* (American polar bear) and *Ursus maritimus* (polar bear) as sister taxa and another clade of *Ursus arctos horribilis* (brown bear) and *U. arctos* (grizzly bear) as sister taxa. Within the Phocidae, *Phoca* (harbor seal) was the basal-most taxon, followed by *Monachus* (Hawaiian monk seal), the *Leptonychotes* (Weddell seal), and finally a clade of two *Mirounga* spp.: *Mirounga angustirostris* (Northern elephant seal) and *Mirounga leonina* (Southern elephant seal). A one species representative of the Family *Odobenidae* was available; consequently, *Odobenus* (Pacific walrus) grouped as basal with members of the Family *Otariidae*, which included *Callorhinus* (Northern fur seal), *Eumetopias* (Stellar sea lion), and *Zalophus* (California sea lion). Similarly, a single species representative of Families *Hyaenidae* and *Herpestidae* were available; consequently, *Hyaena* (hyaena) and *Suricata* (meerkat) formed a sister relationship. In the Felidae, the three *Panthera* spp. formed a monophyletic group, with *Panthera uncia* (snow leopard) forming the basal-most taxon and *Panthera tigris* (tiger) and *Panthera leo* (lion) forming a sister relationship, followed by *Leopardus* (snow leopard), *Lynx* (Canadian lynx), *Puma* (mountain lion), and a monophyletic clade including *Acinonyx* (cheetah) and *Herpailurus* (jaguarundi) as sister taxa, and *Felis* (domestic cat) and *Prionailurus* (leopard cat) as sister taxa.

Order Primates--Composed of eleven families, the Primates (Figs. 1 and 11) can be divided into two large clades, one group containing the Suborder Strepsirrhini (Families Galagidae bushbabies, Indriidae-sifakas, Lemuridae- true lemurs, and Cheirogaleidae-mouse lemurs) and the second including the Suborder Haplorhini (Families Tarsiidae-tarsiers, Cebidae-capuchins and squirrel monkeys, Aotidae-night monkeys, Callitrichidae-marmosets and tamarins, Hylobatidae gibbons, Hominidae-apes, and Cercopithecidae-baboons and macaques). Within the Strepsirrhini (Infraorder Lemuriformes), Galagidae was placed as the basal-most taxon, followed by Indriidae, and then Cheirogaleidae and Indriidae, which shared a sister relationship. Within the Haplorhini, Tarsiidae formed the basal-most taxon (Infraorder Tarsiiformes), followed by a cladogenic event that divided the Infraorder Simiiformes into two clades, one large group containing the Parvorder Platyrrhini (New World Monkeys: Families Cebidae, Aotidae, and Callitrichidae) and the second comprising the Parvorder Catarrhini (Old World anthropoids: Families Hylobatidae, Hominidae, and Cercopithecidae). Within the Platyrrhini, Cebidae was the basal-most taxon, followed by Callitrichidae and Aotidae, which grouped as sister taxa, and in the Catarrhini, Cercopithecidae was the basal-most taxon, followed by Hylobatidae and Hominidae which grouped as sister taxa.

Primates comprised the second-most speciose Order (n=30) in the *Zan* tree, with all genera correctly placed within their respective families (Figs. 1 and 12). Because the Families Galagidae (*Otolemur*, Northern greater galago), Indriidae (*Propithecus*, coquerel sifaka), Cheirogaleidae (*Microcebus*, gray mouse lemur), and Lemuridae (*Lemur*, ring-tailed lemur), each contained a single genus in this study, the species-level relationships were identical to that depicted in the familial-level comparison, with *Otolemur* as the basal-most taxon, followed by *Propithecus*, and then *Microcebus* and *Lemur* as sister taxa. Only one representative of the Tarsiiformes (*Tarsius*, Philippine tarsier) was available; consequently, *Tarsius* was placed as basal to the clade containing the 25 genera in the Simiiformes. Two groups were depicted within the Platyrrhini, the first containing *Callithrix* (white-tufted ear marmoset) and *Aotus* (Ma's night monkey) as sister taxa and the second clade contained *Saimiri* (Bolivian squirrel monkey), *Sapajus* (tufted capuchin), and *Cebus* (white-faced

capuchin), with *Saimiri* placed as the basal taxon. Within the Haplorhini, *Gorilla* (gorilla) and *Nomascus* (Northern white-cheeked gibbon) formed a sister relationship and were placed as basal to the entire haplorrhine clade. The next divergence event led to the remaining members of the Hominidae, the Hylobatidae, and also the entire Cercopithecidae. One species representative of Hylobatidae was available; consequently, *Nomascus* grouped with *Gorilla* in Hominidae. The remaining species of the Hominidae consisted of both *Homo* spp., *H. neanderthalensis* (neanderthal) and *H. sapiens* (human) forming a sister relationship as well as both *Pan* spp., *P. troglodytes* (chimpanzee) and *P. paniscus* (pygmy chimpanzee). In the Family Cercopithecidae, the single species of *Piliocolobus* (Ugandan red colobus) formed the basal-most taxon, followed by *Trachypithecus* (Francois' leaf monkey), and both species of *Rhinopithecus* spp., *R. roxellana* (golden snub-nosed monkey) and *R. bieti* (black-and white snub-nosed monkey). The next divergence event depicted two clades, one of which included the three species of *Macaca*, (*M. fascicularis*-crab-eating macaque, *M. mulatta*-Rhesus macaque, and *M. nemestrina*-pig-tailed macaque), and the second clade consisted of *Papio* (Hamadryas baboon) as the basal-most taxon, followed by *Mandrillus* (drill), *Theropithecus* (gelada), and then *Chlorocebus* (green monkey) and *Cercocebus* (sooty mangabey).

Order Rodentia-- Rodentia (Figs. 1 and 13) comprised 12 families. The *Zan* tree depicted a clade containing the Suborders Hystricomorpha (Families Caviidae-guinea pigs and relatives, Chinchillidae-chinchillas and relatives, Octodontidae-degus and relatives, Heterocephalidae- naked mole-rats, and Bathyergidae-blemsols or mole-rats) and Sciuromorpha (Family Sciuridae-squirrels and relatives) as well as another group containing the remaining six rodent families, representing Castorimorpha (Family Heteromyidae-kangaroo rats and relatives) and Myomorpha (Families Dipodidae-jerboas and relatives, Spalacidae-Old World mole rats, Gerbillidae- gerbils and muroid rodents, Cricetidae-New World rats and mice, and Muridae-Old World rats and mice).

Rodentia comprised the largest order in the *Zan* tree with 32 species, all of which grouped within genera from their respective families (Figs. 1 and 14). Within the Hystricomorpha, a single initial divergence event led to two clades. The first clade included single species from each of the following families: Caviidae (*Cavia*-guinea pig), Chinchillidae (*Chinchilla*-chinchilla), and Octodontidae (*Octodon*-degu); consequently, all three grouped together, with *Chinchilla* and *Octodon* placed as sister taxa. The second clade consisted of the remaining families within the Hystricomorpha, Heterocephalidae (*Heterocephalus*- naked mole rat) and Bathyergidae (*Fukomys*-Damara mole-rat). The next divergent event led to the Sciuromorpha, which consisted of species within Sciuridae grouped into two clades: one clade included *Uroditellus* (arctic ground squirrel) and *Ictidomys* (thirteen-lined ground squirrel) as sister taxa and the other clade included the three *Marmota* spp., *M. monax* (groundhog), *M. marmota* (alpine marmot), and *M. flaviventris* (yellow-bellied marmot). Yet another divergence event led to the Castorimorpha, which was depicted by two *Dipodomys* spp., *D. ordii* (Ord's kangaroo rat) and *D. spectabilis* (banner-tailed kangaroo rat). The final divergence event led to the speciose suborder Myomorpha, which included 20 species. *Jaculus* (Egyptian jerboa) and *Spalax* (Upper Galilee Mountains blind mole-rat) were the single representative species available for Dipodidae and Spalacidae, respectively; consequently, *Jaculus* and *Spalax* appear as basal to the entire Myomorpha clade. The single representative of Gerbillidae, *Meriones* (Mongolian gerbil) was next to diverge, followed by the Cricetidae and Muridae. Within the Cricetidae, *Mesocricetus* (golden hamster) and *Cricetulus* (Chinese hamster) formed a sister relationship, *Onychomys* (Southern grasshopper mouse), and the two *Peromyscus* spp., *P. leucopus* (white-footed deermouse) and *P. maniculatus* (North American deermouse) formed a clade. Also, *Myodes* (bank vole), *Arvicola* (European water vole), and the two *Microtus* spp., *M. orchrogaster*

(prairie vole) and *M. oregoni* (creeping vole) formed a monophyletic group. Within the Muridae, the two *Rattus* spp., *R. rattus* (brown rat) and *R. norvegicus* (domestic rat) formed a sister relationship, followed by *Arvicanthis* (African grass rat) and *Grammomys* (woodland thicket rat) which also formed a sister relationship. The next divergence event led to *Mastomys* (Southern multimammate mouse), followed by a clade of three *Mus* spp., *M. pahari* (Gairdner's shrewmouse), *M. caroli* (Ryukyu mouse), and *M. musculus* (house mouse).