Evolution of the patellar sesamoid bone in mammals

SUPPLEMENTARY INFORMATION: Tables, Figures and References

Supplementary Table S1: Mammals[$]

Higher taxa (partial)	**Genus sp.**	**Estimated. age of specimen, location**	**Patellar state** **0/1/2** **(absent/ 'patelloid'/ present)**	**Comments**[#]
Sinoconodonta	*Sinoconodon rigneyi (Kielan-Jaworowska, Cifelli & Luo, 2004)*	Jurassic	0	Patellar groove absent, suggests no patella *Sinoconodon* is included on our phylogeny within tritylodontids.
Morganucodonta	*Megazostrodon rudnerae (Jenkins & Parrington, 1976)*	Late Triassic, southern Africa	0	
Morganucodonta	*Eozostrodon sp. (Jenkins et al., 1976)*	Late Triassic, Wales	0	Asymmetric patellar groove, specimens disarticulated so it is hard to assess the patella but appears absent
Docodonta	*Castorocauda lutrasimilis (Ji, Luo, Yuan et al., 2006)*	164 Mya, mid-Jurassic, China	0	Semi-aquatic adaptations
Docodonta	*Agilodocodon scansorius* (Meng, Ji, Zhang *et al.*, 2015)	164 Mya, mid-Jurassic, China	0	
Docodonta	*Docofossor brachydactylus* (Luo, Meng, Ji *et al.*, 2015)	160 Mya	0	
Docodonta	*Haldanodon exspectatus (Martin, 2005b)*	150-155 Mya, Late Jurassic, Portugal	0	Shallow patellar groove
Australosphenida	*Asfaltomylos patagonicus (Martin, 2005a)*	Mid-Jurassic, South America	?	Postcranial material absent
Australosphenida Monotremata	*Ornithorhynchus anatinus (Herzmark, 1938; Rowe, 1988)*	Extant	2	Platypus, genome sequenced (Warren, Hillier, Marshall Graves *et al.*, 2008)

Australosphenida Monotremata	*Tachyglossus* + *Zaglossus* spp. *(Herzmark, 1938; Rowe, 1988)*	Extant	2	Echidnas
Mammaliaformes indet.	*Fruitafossor windscheffeli (Luo & Wible, 2005)*	150 Mya, Late Jurassic, Colorado	0	Phylogenetic status uncertain
Mammaliaformes indet.	*Volaticotherium antiquus (Meng, Hu, Wang et al., 2006)*	Late Jurassic/Early Cretaceous	?	Hindlimb material incomplete
Eutriconodonta	*Jeholodens jenkinsi (Ji, Luo & Ji, 1999)*	120-125 Mya, Early Cretaceous, China	0	Poorly developed patellar groove
Eutriconodonta	*Gobiconodon spp. (Jenkins & Schaff, 1988)*	100-110 Mya, Early Cretaceous, Montana	0	Shallow patellar groove
Eutriconodonta	*Liaoconodon hui (Meng, Wang & Li, 2011)*	120-125 Mya, Early Cretaceous, China	0	No patella visible in figure of well-preserved hindlimb
Eutriconodonta	*Yanoconodon allini (Luo, Chen, Li et al., 2007)*	120-125 Mya, Early Cretaceous, China	0	
Eutriconodonta	*Repenomamus giganticus (Hu, Meng, Wang et al., 2005)*	Early Cretaceous, China	0	
Allotheria "Haramiyida"	*Haramiyavia (Butler, 2000; Jenkins, Gatesy, Shubin et al., 1997)*	Late Triassic, Greenland	?	
Allotheria "Haramiyida" (?)	*Megaconus mammaliaformis (Zhou, Wu, Martin et al., 2013)*	Mid-Jurassic	0	No patella visible in figure of well-preserved hindlimb
Allotheria Euharamiyida	*Arboroharamiya jenkinsi (Bi, Wang, Guan et al., 2014; Zheng, Bi, Wang et al., 2013)*	Mid-late Jurassic	0	No patella visible in figure of well-preserved hindlimb
Allotheria Euharamiyida	*Shenshou lui (Bi et al., 2014)*	Mid-Jurassic, China	0	Coded as absent by Bi et al. (2014); no patella visible in figure of well-preserved hindlimb
Allotheria Euharamiyida	*Xianshou* spp. *(Bi et al., 2014)*	Mid-Jurassic, China	0	Coded as absent by Bi et al. (2014); no patella visible in figure of well-

				preserved hindlimb
Allotheria Multituberculata	*Rugosodon eurasiaticus (Yuan, Ji, Meng et al., 2013)*	Late Jurassic	0	
Allotheria Multituberculata	*Chulsanbaatar vulgaris (Kielan-Jaworowska & Gambaryan, 1994)*	Late Cretaceous, Mongolia	2	
Allotheria Multituberculata	*Kryptobaatar dashzevegi (Kielan-Jaworowska et al., 1994)*	Late Cretaceous, Mongolia	?	
Allotheria Multituberculata	*Nemegbaatar gobiensis*	Late Cretaceous, Mongolia	?	
Allotheria Multituberculata	*Plagiaulacidans* spp. *(Luo, Yuan, Meng et al., 2011)*	Mid-Jurassic to Early Cretaceous	?	As stated in character matrix of Luo et al. (2011), but stated as absent by others (Yuan *et al.*, 2013)
Allotheria Multituberculata	*Cimolodontans* spp. *(Luo et al., 2011)*	Cretaceous to Early Cenozoic	?	As stated in character matrix of Luo et al. (2011), but stated as absent by others (Yuan *et al.*, 2013)
Allotheria Multituberculata	*Ptilodus kummae (Jenkins & Krause, 1983)*	Late Paleocene, Canada	2	
Allotheria Multituberculata	*Eucosmodon (Granger & Simpson, 1929; Simpson & Elftman, 1928)*	Paleocene	?	Femur has patellar groove, status of patella not reported
Symmetrodonta Spalacotheroidea	*Zhangheotherium quinquecuspidens (Hu, Wang, Luo et al., 1997; Luo & Ji, 2005)*	120-125 Mya, Early Cretaceous, China	2	Noted by Luo & Ji (2005), not by Hu et al. (1997)
Symmetrodonta Spalacotheroidea	*Maotherium asiaticus (Ji, Luo, Zhang et al., 2009)*	120-125 Mya, Early Cretaceous, China	?	
Symmetrodonta Spalacotheroidea	*Akidolestes cifelli (Chen & Luo, 2012)*	120-125 Mya, Early Cretaceous, China	0	
Eupantotheria	*Henkelotherium guimarotae (Molinero, 2003; Vazquez-Molinero, Martin, Fischer et al.,*	Late Jurassic, Portugal	0	

	2001)			
Eupantotheria	*Vincelestes neuquenianus (Bonaparte, 2008; Rougier, 1993)*	Early Cretaceous, South America	0	
Eupantotheria	Dryolestids (spp).	Late Jurassic to early Cenozoic	?	Hindlimb material missing
"Theria"	*Juramaia sinensis (Luo et al., 2011)*	160-165 Mya, late Jurassic, China	?	Hindlimbs missing, placement relative to basal Theria uncertain
"Theria"	*Eomaia scansoria (Ji, Luo, Yuan et al., 2002; O'Leary, Bloch, Flynn et al., 2013b)*	120-125 Mya, Early Cretaceous, China	2	Originally placed in Placentalia, restated as "Theriimorpha" immediately adjacent to basal Theria
Metatheria	*Sinodelphys szalayi (Luo, Ji, Wible et al., 2003)*	120-125 Mya, Early Cretaceous, China	0	Earliest putative metatherian
Metatheria	*Asiatherium reshetovi (Szalay & Trofimov, 1996; Trofimov & Szalay, 1994)*	80 Mya, late Cretaceous, Mongolia	0	Lacks patellar groove on distal femur
Metatheria Deltatheroidea	*Deltatherium* spp. *(Rougier, Wible & Novacek, 1998)*	Cretaceous, Mongolia	?	
Metatheria	*Pucadelphys andinus (Macrini, De Muizon, Cifelli et al., 2007)*	Early Paleocene, South America	0	As per character matrices (Luo *et al.*, 2011; Wible, Rougier, Novacek *et al.*, 2007)
Metatheria Marsupialia	*Mayulestes ferox (De Muizon, 1994; De Muizon, 1998)*	Early Paleocene, South America	0	Carnivorous marsupial As per character matrices (Luo *et al.*, 2011; Wible *et al.*, 2007)
Metatheria Marsupialia	*Herpetotherium fugax (Horovitz, Ladeveze, Argot et al., 2008; Horovitz, Martin, Bloch et al., 2009)*	Oligocene, Wyoming	0	
Metatheria Marsupialia Borhyaenoidea	*Callistoe vincei (Argot & Babot, 2011)*	Eocene	2	Carnivorous marsupial
Metatheria Marsupialia Borhyaenoidea	*Prothylacinus patagonicus (Argot, 2003a)*	Early Miocene, Patagonia	2	Carnivorous marsupial
Metatheria Marsupialia	*Boryhyaena tuberata (Argot,*	Early Miocene, Patagonia	?	Carnivorous marsupial

Borhyaenoidea	*2003a)*			
Metatheria Marsupialia Borhyaenoidea	*Artiodictis sinclairi (Forasiepi, 2004)*	Early Miocene, Argentina	2	Carnivorous marsupial
Metatheria Marsupialia Borhyaenoidea	*Sipalocyon* sp. *(Sinclair, 1905)*	Mid-Miocene	2	Originally called "*Amphiproviverra"* (Argot, 2003b)
Metatheria Marsupialia Borhyaenoidea	*Lycopsis longirostris (Argot, 2004)*	Mid-Miocene, South America	?	Carnivorous marsupial
Metatheria Marsupialia Thylacinidae	*Thylacinus cynocephalus (De Vriese, 1909)*	20th century, Australia	0	Thylacine- "Tasmanian tiger" or "wolf"; recently extinct. Patella fibrocartilaginous? See Fig. S3 Y,Z
Metatheria Marsupialia Didelphidae	*Didelphis virginiana (Szalay & Sargis, 2001)*	Extant, North America	0	North American opossum. Coding for this taxon is debatable—some studies claim it has an ossified patella in older adults (Szalay *et al.*, 2001). More study is needed to confidently code it
Metatheria Marsupialia Didelphidae	*Monodelphis domestica*	Extant, South America	0	Gray short-tailed opossum. Genome sequenced (Mikkelsen, Wakefield, Aken *et al.*, 2007)
Metatheria Marsupialia Didelphidae	*Metachirus nudicaudatus (Szalay et al., 2001)*	Extant, Central America	0	Brown four eyed opossum
Metatheria Marsupialia Macropodidae	*Macropus spp.* and relatives *(Reese, Pfuderer, Bragulla et al., 2001)*	Extant, Australia	1	Kangaroos, wallabies. As noted above for other marsupials and in the main text, coding for this taxon is complicated by the possibility that the patella may only ossify in older adults—e.g. Figs. S3 U,V,W,X
Metatheria Marsupialia Dasyuridae	*Dasyurus spp.* and relatives *(Reese et al., 2001)*	Extant, Australia	1	Dasyurids (marsupial rat, cat, Tasmanian devil, quoll, etc)
Metatheria Marsupialia Vombatiformes	*Diprotodon spp.*	Pleistocene, Australia	0	Giant, elephant-sized wombatids (extinct)- patella possibly unossified; see Fig. S2 K, L
Metatheria Marsupialia Vombatiformes Vombatidae	*Lasiorhinus latifrons (Reese et al., 2001)*	Extant, Australia	1	Southern hairy-nosed wombat
Metatheria Marsupialia Burramyidae	*Acrobates pygmaeus, Burramys parvus (Reese et al.,*	Extant, Australia	1	Feathertail glider and mountain pygmy possum

	2001)			
Metatheria Marsupialia Phalangeridae	*Trichosurus Vulpecula (Reese et al., 2001)*	Extant, Australia	1	Brush-tailed possum
Metatheria Marsupialia Pseudocheiridae	*Pseudocheirus peregrinus (Reese at al., 2001)*	Extant, Australia	1	Common ringtailed possum
Petauridae	*Petaurus (Slade, 1810)*		0	Absence of bony patella
Caluromyidae	*Caluromys* and relatives *(Flores, 2009)*		0	Absence of bony patella
Metatheria Marsupialia Vombatiformes Phascolarctidae	*Phascolarctus cinereus (Reese et al., 2001)*	Extant, Australia	1	Koala
Metatheria Marsupialia Peramelidae	*Isoodon obesulus (Reese et al., 2001)*	Extant, Australia	2	Southern bandicoot Has patelloid ("suprapatella") also
Metatheria Marsupialia Peramelidae	*Perameles nasuta (Reese et al., 2001)*	Extant, Australia	2	Long-nosed bandicoot Has patelloid ("suprapatella") also
Metatheria Marsupialia Notoryctidae	*Notoryctes typhlops (Johnson & Walton, 1989; Osgood, 1921; Warburton, 2006)*	Extant, Australia	2	Marsupial mole
Metatheria Marsupialia Notoryctidae	*Notoryctes caurinus (Osgood, 1921; Warburton, 2006; Warburton, Wood, Lloyd et al., 2003)*	Extant, Australia	2	Marsupial mole
Metatheria Marsupialia Microbiotheriidae	*Dromiciops gliroides (Szalay et al., 2001)*	Extant, South America	0	Monito del monte, little bush monkey
Metatheria Marsupialia Caenolestida	*Palaeothentes* spp. *(Abello & Candela, 2010)*	Miocene, South America	?	Incomplete hindlimb material
Metatheria Marsupialia Caenolestida	*Rhyncholestes raphanurus (Szalay et al., 2001)*	Extant, South America	2	Long-nosed shrew opossum

Metatheria Marsupialia Caenolestida	*Caenolestes fulginosus (Osgood, 1921)*	Extant, South America	2	Dusky shrew opossum
Metatheria Marsupialia Tarsipidae	*Tarsipes rostratus (Osgood, 1921; Waterhouse, 1846)*	Extant, Australia	2	Honey possum
Eutheria	*Asioryctes nemegetensis (Wible, Rougier & Novacek, 2005)*	Late Cretaceous, Mongolia	?	Basal eutherian but not placental per O'Leary et al. (2013)
Eutheria	*Ukhaatherium nessovi (Horovitz, 2003)*	70-75 Mya Late Cretaceous, Mongolia	2	Basal eutherian but not placental per O'Leary et al. (2013)
Eutheria	*Zalambdalestes lechei (Wible et al., 2005)*	70-75 Mya Late Cretaceous, Mongolia	2	Basal eutherian but not placental per O'Leary et al. (2013)
Eutheria Taeniodonta	*Onychodectes tisonensis (Matthew, 1937; Schoch, 1986)*	Paleocene	2	
Eutheria Taeniodonta	*Psittacotherium multifragum (Schoch, 1986)*	Paleocene	2	
Eutheria Taeniodonta	*Stylinodon mirus (Schoch, 1986)*	Paleocene (but elsewhere described as Eocene)	2	
Eutheria Pantodonta	*Bemalambda* spp. *(Chow, Zhang, Wang et al., 1977)*	Paleocene	2	
Eutheria Pantodonta	*Pantolambdidae* spp. *(Chow et al., 1977; Simons, 1960)*	Paleocene	2	
Eutheria Pantodonta	*Coryphodon* sp. *(Cope, 1883)*	Paleocene	2	
Eutheria Pantodonta	*Titanoides* sp. *(Patterson, 1934; Simons, 1960)*	Paleocene	2	
Eutheria Apatemyidae	*Apatemys chardini (Koenigswald, Rose, Grande et al., 2005)*	Eocene	2	
Eutheria Notoungulata	*Allalmeia atalaensis (Lorente, Gelfo & Lopez, 2014)*	Eocene	2	South American ungulate

Eutheria Notoungulata	*Toxodon* sp. *(Schockey, 2001)*	Pliocene/Pleistocene	2	South American ungulate; see Fig. S2 G,H
Eutheria Dinocerata	*Prodinoceras* sp. *(Gunnell, 2008)*	Paleocene/Eocene	2	
Eutheria Dinocerata	*Uintatherium anceps (Wheeler, 1961)*	Eocene	2	See Fig. S1 W,X
Eutheria Proterotheriidae	*Eoauchenia* sp. *(Shockey, 2001)*	Miocene(?)	2	South American early litoptern
Eutheria Xenarthra Cingulata	*Trachycalyptus* sp. *(Shockey, 2001)*	Miocene	2	Or related South American glyptodonts; e.g. *Panochthus*, Fig. S2I. Extinct ground sloths, e.g. *Scelidodon*, likewise have a patella—Fig. S2J; as do extant Xenarthra; Fig. S3
Eutheria Afrotheria Embrithopoda	*Arsinoitherium zitteli (Andrews, 1906)*	Eocene/Oligocene	2	Large relative to elephants, sirenians. See Fig. S1 U,V
Eutheria Leptictidae	*Leptictidium nasutum (Von Koenigswald, Storch & Richter, G.1992)*	Eocene	2	Visible in photo
Eutheria Afrotheria Paenungulata	*Carodnia vieirai (Couto, 1952; O'Leary et al., 2013b)*	Paleocene/Eocene	2	South American ungulate, patella marked as present in O'Leary et al. (2013) Morphobank study 773
Eutheria Afrotheria Desmostylia	*Paleoparadoxia* sp. *(Yanofsky, 1998)*	Miocene	2	Renamed (Domning & Barnes, 2007)
Eutheria Afrotheria Desmostylia	*Desmostylus hesperus (Inuzuka, 2009)*	Miocene	2	
Eutheria Afrotheria Sirenia	*Protosiren* sp. *(Zalmout, 2008)*	Eocene	2	Early sirenian with hindlimbs from Egypt
Eutheria Afrotheria Sirenia	*Pezosiren portelli (Domning, 2001)*	Eocene	2	Early sirenian with hindlimbs from Jamaica
Eutheria Afrotheria Proboscidea	*Numidotherium koholense (Court, 1994)*	Eocene	?	Hindlimb material lacking
Eutheria Afrotheria Proboscidea	*Moeritherium* sp. *(Delmer, Mahboubi, Tabuce et al., 2006; O'Leary et al., 2013b)*	Eocene	2	Marked as present, with photograph, in O'Leary et al. (2013) Morphobank study 773

Eutheria Glires	*Rhombomylus turpanensis (Meng, Hu & Li, 2003; O'Leary et al., 2013b)*	Eocene	2	Side branch related to early rodents
Eutheria Glires Rodentia Paramyidae	*Pseudotomus eugenei (Dunn & Rasmussen, 2007; Dunn, 2009)*	Eocene	2	
Eutheria Glires Rodentia Paramyidae	*Paramys delicates (Matthew, 1910; Wood, 1962)*	Eocene	2	
Eutheria Glires Rodentia Sciurognathi	*Ischyromys* sp. *(Scott, Jepsen & Elmer, 1937)*	Oligocene	2	
Eutheria Glires Rodentia	*Nonanomalurus soniae (Pickford, Senut, Musalizi et al., 2013)*	Miocene	2	
Eutheria Glires Rodentia	*Nonanomalurus soniae (Pickford et al., 2013)*	Miocene	2	
Eutheria Primates Haplorhini	*Teilhardina belgica (Gebo, Smith & Dagosto, 2012)*	Eocene	?	Hindlimb material incomplete
Eutheria Plesiadapiformes	*Plesiadapis cookei (Bloch & Boyer, 2007)*	Paleocene	2	
Eutheria Primates Notharctidae	*Notharctus* spp. *(Gregory, 1920)*	Eocene	2	Fig. S1 S, T
Eutheria Primates Notharctidae	*Darwinius masillae (Franzen, Gingerich, Habersetzer et al., 2009)*	Eocene	2	
Eutheria Primates Notharctidae	*Pelycodus jarrovii (Cope, 1885)*	Eocene	2	
Eutheria Primates Haplorhini	*Archicebus achilles (Ni, Gebo, Dagosto et al., 2013)*	Eocene	2	
Eutheria Primates Haplorhini Omomyidae	*Omomys* sp. *(Anemone & Covert, 2000)*	Eocene	2	
Eutheria Primates	*Pliopithecus* sp.	Miocene	2	

Haplorhini	*(Zapfe, 1958)*			
Eutheria Primates Hominoidea	*Oreopithecus* sp. *(Schoch, 1986)*	Miocene	2	
Eutheria Primates Hominoidea	*Proconsul* spp. *(Ward, Ruff, Walker et al., 1995)*	Miocene	2	
Eutheria Primates Hominoidea	*Nacholapithecus kerioi (Nakatsukasa, Kunimatsu, Shimizu et al., 2012)*	Miocene	2	
Eutheria Primates Hominoidea	*Pierolapithecus catalaunicus (Pina, Almecija, Alba et al., 2014)*	Miocene	2	
Eutheria Primates Hominidae	*Australopithecus afarensis (Alemseged, Spoor, Kimbel et al., 2006)*	Pliocene	2	"Lucy" hindlimb incomplete, patella noted in juvenile, est. 3 years old
Eutheria Primates Hominidae	*Australopithecus robustus (Susman, 1988)*	Pliocene/Pleistocene	2	Previously *Paranthropus robustus*
Eutheria Primates Hominidae	*Homo* spp. *(Trinkhaus, 2000)*	850, 300, 150 Kya, Pleistocene/Extant, Africa/Eurasia	2	
Eutheria Pholidota	*Eomanis waldi (Storch & Richter, 1992)*	Eocene	2	Early pangolin
Eutheria Palaeanodonta	*Ernanodon antelios (Kondrashov & Agadjanian, 2012)*	Paleocene	2	
Eutheria Palaeanodonta	*Brachianodon westorum (Gunnell & Gingerich, 1993)*	Eocene	2	
Eutheria Creodonta Hyaenodontidae	*Arfia shoshoniensis (Gingerich & Deutch, 1989)*	Eocene	2	Side branch to extant carnivores
Eutheria Creodonta Oxyaenidae	*Oxyaena* sp., *Patriofelis*, sp. *(Osborn, 1900; Wortman, 1894)*	Eocene	2	Side branch to extant carnivores

Eutheria Carnivoramorpha	*Paroodectes feisti (Springhorn, 1992)*	Eocene	2	Visible in photo; side branch to extant carnivores
Eutheria Carnivoramorpha	*Miacis* spp. *(Spaulding & Flynn, 2012)*	Eocene	?	Incomplete hindlimb material
Eutheria Carnivoramorpha	*Vulpavus ovatus (O'Leary et al., 2013b; Spaulding et al., 2012)*	Eocene	2	Marked as present, with photo, in O'Leary et al. (2013) Morphobank study 773
Eutheria Carnivora Nimravidae	*Hoplophoneus primaevus (Burnham, Rothschild, Babiarz et al., 2013)*	Oligocene	2	Fig. S1K, L
Eutheria Carnivora Nimravidae	*Pogonodon brachyops (Cope, 1883)*	Miocene	2	
Eutheria Carnivora Mustelidae	*Brachypsalis modicus (Galbreath, 1955)*	Miocene	2	
Eutheria Chiroptera	*Icaronycteris index (Jepsen, 1966; O'Leary et al., 2013b)*	Eocene	2	Early bat, patella marked as present, with photograph, in O'Leary et al. (2013) Morphobank study 773
Eutheria Chiroptera	*Tachypteron franzeni (Storch, Sige & Habersetzer, 2002)*	Eocene	2	Early bat
Eutheria Chiroptera (O'Leary *et al.*, 2013b)(O'Leary *et al.*, 2013b)(O'Leary *et al.*, 2013b)(O'Leary et al., 2013b)	*Onychonycteris finneyi (O'Leary et al., 2013b)*	Eocene	2	Early bat, patella marked as present, with photograph, in O'Leary et al. (2013) Morphobank study 773
Eutheria Microchiroptera	*Microchiroptera* spp. *(Smith, Holladay & Smith, 1995)*	Extant	2	Bats
Eutheria Microchiroptera	*Lasiurus cinereus (Czaplewski, Morgan & McLeod, 2008)*	Extant	2	Hoary bat
Eutheria Megachiroptera	*Cynopterus marginatus (Pearson &*	Extant	2	Lesser short-nosed fruit bat

	Davin, 1921)			
Eutheria Megachiroptera	*Rousettus aegypticus (Smith et al., 1995)*	Extant	2	Egyptian fruit bat
Eutheria Megachiroptera	*Cynopterus brachyotis (Smith et al., 1995)*	Extant	2	Lesser short-nosed fruit bat
Eutheria Megachiroptera	*Haplonycterus fischeri (Smith et al., 1995)*	Extant	2	Fischer's pygmy fruit bat
Eutheria Megachiroptera	*Pteropus* spp. *(Smith et al., 1995)*	Extant	0	"Flying foxes"
Eutheria Condylarthra(?)	*Protungulatum donnae (Archibald, Zhang, Harper et al., 2011)*	Paleocene	?	Incomplete postcrania
Eutheria Condylarthra	*Arctocyon primaevus (Argot, 2012)*	Paleocene	2	
Eutheria Condylarthra	*Mioclaenus* sp. *(Cope, 1883; Matthew, 1937; Schlosser, 1887)*	Paleocene/Eocene	2	
Eutheria Condylarthra	*Phenacodus* spp. *(Cope, 1883; Osborn, 1898; Rose, Chew, Dunn et al., 2012; Thewissen, 1990)*	Paleocene/Eocene	2	
Eutheria Condylarthra	*Copecion brachypternus (Thewissen, 1990)*	Paleocene/Eocene	2	
Eutheria Condylarthra	*Tetraclaenodon puercensis (Kondrashov & Lucas, 2012; Matthew, 1897)*	Paleocene/Eocene	2	Originally named "*Euprotogonia"*, reported in Eocene but not Paleocene specimen, earlier hindlimb material incomplete
Eutheria Condylarthra	*Chriacus* sp. *(Rose, 1987)*	Eocene	2	
Eutheria Condylarthra	*Meniscotherium* sp. *(Cope, 1883; Guzin, 1965)*	Eocene	2	
Eutheria Condylarthra	*Hyopsodus paulus (O'Leary et al., 2013b)*	Eocene	2	Marked as present, including photo, in O'Leary et al. (2013) Morphobank study 773

Eutheria Mesonychia	*Pachyaena gracilis (O'Leary & Rose, 1995)*	Eocene	2	
Eutheria Mesonychia	*Pachyaena ossifraga (Zhou, Sanders & Gingerich, 1992)*	Eocene	2	
Eutheria Mesonychia	*Mesonyx obtusidens (Cope, 1873; Cope, 1883; O'Leary et al., 2013b)*	Eocene	2	
Eutheria Perissodactyla Chalicotheriidae	*Litolophus gobiensis (Bin, 2009; Warburton, 2004)*	Eocene	2	
Eutheria Perissodactyla Palaeotheriidae	*Hyracotherium granger (Cope, 1883; Danaher, Shockey & Mihlbachler, 2009; Williamson, Brusatte, Carr et al., 2012; Wood, Bebej, Manz et al., 2011)*	Eocene	2	Stem equid; or "*Eohippus*" (controversial taxonomy)
Eutheria Perissodactyla	*Hyrachyus* sp. *(Danaher et al., 2009)*	Eocene	2	
Eutheria Perissodactyla Equidae	*Mesohippus grallipes (Sinclair, 1925; Zheng et al., 2013), M. bairdi (O'Leary et al., 2013b)*	Oligocene	2	Fig. S1 A, B.
Eutheria Perissodactyla Equidae	*Propalaeotherium hassiacum (Franzen, 1992)*	Eocene	2	Originally considered a palaeotherid, re-interpreted as early equid (Abello *et al.*, 2010)
Eutheria Perissodactyla Equidae	*Archaeohippus ultimus(Sullivan, 2003)*	Miocene	2	
Eutheria Perissodactyla Equidae	*Plesihippus shoshonensis (Gazin, 1936)*	Pliocene	2	Also called Hagerman's horse
Eutheria Perissodactyla Rhinocerotidae	*Subhyracodon mitis (Pina et al., 2014)*	Eocene	2	Stem rhinoceros
Eutheria Perissodactyla	*Paraceratherium* spp. *(Danaher et*	Oligocene	2	Also called "*Indricotherium*" or "*Baluchitherium*", taxonomy not

Rhinocerotidae	*al., 2009; Mitchell, Pratt, Watson et al., 2014; Osborn, 1921)*			fully resolved. Giant stem rhinoceros
Eutheria Perissodactyla Brontotheriidae	*Palaeosyops paludosus (Leidy, 1873)*	Eocene	2	Rhinoceros-like
Eutheria Perissodactyla Brontotheriidae	*Aktautitan hippopotamopus (Mihlbachler, Lucas, Emry et al., 2004)*	Eocene	2	Rhinoceros-like
Eutheria Perissodactyla Brontotheriidae	*Embolotherium andrewsi (McLaughlin, Mihlbachler & Ellison, 2010; Meredith, Krajewski, Westerman et al., 2009)*	Eocene	2	Rhinoceros-like
Eutheria Artiodactyla	*Diacodexis metsiacus (Alemseged et al., 2006; Rose, 1985)*	Eocene	2	Stem artiodactyl
Eutheria Artiodactyla	*Protoreodon annectens (Ludtke, 2007)*	Eocene	2	
Eutheria Artiodactyla	*Indohyus* sp. *(Cooper, Thewissen, Bajpai et al., 2012)*	Eocene	2	Closely related to early cetaceans
Eutheria Artiodactyla	*Gervachoerus jaegeri (Erfurt & Metais, 2007)*	Eocene	2	
Eutheria Artiodactyla Anthracotheriidae	*Elomeryx armatus (Yuan et al., 2013)*	Oligocene	2	
Eutheria Artiodactyla	*Leptomeryx evansi (Schultz, 1960)*	Eocene/Oligocene	2	Patella documented in widely diverse (Cet)Artiodactyla—e.g. Fig. S3 S, T in juvenile *Hippopotamus*, diminutive *Tragulus*
Eutheria Artiodactyla	*Caenotherium* sp. *(Erfurt et al., 2007)*	Eocene	2	
Eutheria Artiodactyla Ruminantia	*Paratylopus sternbergi (Cope & Matthew, 1915)*	Oligocene	2	

Camelidae				
Eutheria Cetartiodactyla Artiodactyla Merychoidodontidae	*Merychyus major (Morgan, Lander, Cikoski et al., 2009)*	Miocene	2	Cf. Fig. S1 C, D
Eutheria Cetacea	*Pakicetus attocki (Thewissen, Williams, Roe et al., 2001)*	Eocene	?	Very early cetacean with hindlimbs, specimens incomplete but often shown with patella (Fig. S1 M, N)
Eutheria Cetacea	*Maiacetus inuus (Gingerich, Ul-Haq, von Koenigswald et al., 2009)*	Eocene	2	Early cetacean with hindlimbs
Eutheria Cetacea	*Basilosaurus isis (Gingerich, Smith & Simons, 1990)*	Eocene	2	Early cetacean with hindlimbs
Eutheria Cetacea	*Ambulocetus natans (Madar, Thewissen & Hussain, 2002)*	Eocene	2	Early cetacean with hindlimbs. Fig. S1 O, P
Eutheria Cetacea	*Rodhocetus balochistanensis (Gingerich et al., 2009)*	Eocene	2	Early cetacean with hindlimbs
Eutheria Cetacea	*Artiocetus clavis (O'Leary et al., 2013b)*	Eocene	2	Early cetacean with hindlimbs, Marked as present in O'Leary et al. (2013) Morphobank study 773
Eutheria Cetacea	*Dorudon atrox (Uhen, 2004)*	Eocene	2	Early cetacean with very reduced hindlimbs. Fig. S1 Q, R

[$] Early groups are ordered by estimated times of divergence, not by geological age of representative specimens. The Eutheria specifically are ordered as per Figure 7 (from bottom to top), thus by major clades (mostly "orders") and then by geological age of specimens within the major taxa.

[#] Common names in some cases from general sources.

[%] "Condylarthra" probably does not represent a monophyletic group but this term is widely used in the literature and is generally understood (Rose, 2006).

Supplementary Table S2. Genetics of the patella in humans

Syndrome	Gene	Molecular function	Developmental Process
Nail-patella	LMX1B	Transcription factor	Limb patterning
Small patella	TBX4	Transcription factor	Limb patterning
Clubfoot with long bone deficiencies	PITX1	Transcription factor	Limb patterning
Fuhrmann	WNT7A	Cell-cell signalling	Limb patterning
Du Pan	GDF5	Growth factor	Bone growth and differentiation, joint definition/patterning
Multiple pterygium (Escobar variant)	CHRNG	Fetal muscle cholinergic nicotinic receptor	Neuromuscular synaptic signalling
Multiple epiphyseal dysplasia	SL26A2, COL9A2	Sulfate transporter, collagen	Chemistry of connective tissue
Meier-Gorlin	ORC1, ORC4, ORC6, CDT1, CDC6, GMNN	Origin recognition binding	DNA replication, cell division
Roberts	ESCO2	Sister chromatid cohesion acetyltransferase	DNA replication, cell division
RAPADILINO	RECQL4	DNA helicase	DNA replication, cell division
Genitopatellar	KAT6B	Histone acetyltransferase	Chromatin
Proteus	AKT1	Phosphoinositide 3-kinase	Cell growth

Supplementary Figures (S1-S6):

Supplementary Figure S1. Patella in representative mammals of the Paleogene (Eocene, Oligocene) and early Neogene (Miocene). A, B. *Mesohippus* sp. (Oligocene, early horse). C, D. *Merycoidodon (AKA Oreodon) culbertsoni* (late Eocene/early Miocene pig-like), patella attested for Oligocene *Merycoidodon/Oreodon gracilis* and *Oreodon sp*.)(Gilmore, 1906; Leidy, 1869). E, F. *Megacerops sp.* (late Eocene, rhinoceros-like), patella attested for *Megacerops tyleri (Lull, 1905)*. G, H. *Archaeotherium sp.* (cast, Eocene/Oligocene, fanged peccary-like entelodont), patella attested for *Archaeotherium* and related *Daedodon sp.* (originally *Dinohyus*, since renamed)(O'Leary *et al.*, 2013b; Peterson, 1909). I, J. *Hyaenodon gigas* (Eocene/Miocene creodont), patella attested(Hill, 1886). K, L. *Hoplophoneus sp.* (Eocene/Oligocene, feline-like nimravid), patella attested (Turner & Anton, 1997). M, N. *Pakicetus attocki* (Eocene, early cetacean), patella not attested by primary citation. O, P. *Ambulocetus natans* (Eocene, aquatic and ambulatory cetacean), patella attested (Madar *et al.*, 2002). Q, *Dorudon atrox* (aquatic cetacean, upper specimen, pelvis and hindlimbs not visible behind *Ambulocetus* lower specimen). R, *Dorudon atrox* patella closeup, patella attested (Uhen, 2004). S, T. *Notharctus sp.* (Eocene, early primate), patella attested (Gregory, 1920). U, V. *Arsinoitherium zitteli* (Eocene/Oligocene, rhinoceros-like afrotherian), patella documented (Andrews, 1906); exhibit specimen at The Natural History Museum (NHMUK), London, United Kingdom. W, X. *Uintatherium anceps* (Eocene, large-bodied member of the exotic stem-placental clade Dinocerata); exhibit specimen at the Galeries d'Anatomie comparée et de Paléontologie, Paris, France. Specimen numbers (CMNFV = Canadian Museum of Nature, fossil vertebrates): A, B. CMNFV 52723. C, D. CMNFV 8181. E, F. CMNFV 341. G, H. CMNFV 52721. I, J. CMNFV 52756. K, L. CMNFV 52785. M, N. CMNFV 51974. O, P. CMNFV 51838. Q, R. CMNFV 51837. S, T. CMNFV 52972.

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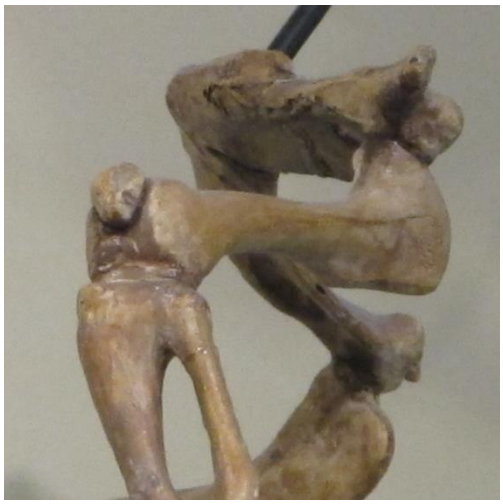

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Supplementary Figure S2. Patella in representative mammals of the late Neogene (Pliocene) and early Quaternary (Pleistocene). A, B. *Castoroides ohioensis* (Pleistocene, giant beaver)(Erickson, 1962). C, D. *Smilodon fatalis* (Pleistocene, sabretooth cat)(Berta, 1987; Raymond & Prothero, 2010). E. *Mammuthus sp.* (Pliocene/mid-Holocene, mammoth, primary collection). F. *Mammut americanum* (Pleistocene, American mastodon)(Woodman & Branstrator, 2008). G, H. *Toxodon* sp. (Plio-Pleistocene, South American notoungulate). I. *Panocthus* sp., glyptodontid (Xenarthra; giant Pleistocene armoured relative of armadillos). J. *Scelidodon* sp. (Xenarthra; giant Pleistocene ground sloth). K, L. *Diprotodon* sp. (giant Pleistocene wombatid marsupial with no evidence of an ossified patella). Specimen numbers: A, B. CMNFV 44757 (CMNFV = Canadian Museum of Nature, fossil vertebrates). C, D. UCMP exhibit specimen (Univ. Museum of Paleontology, Berkeley, California). E. CMNFV 15490; 18994; 19378; 24031; 26771; 27311; 27629; 31645; 32009; 33606; 39632; 43140; 43280; 44321; (1 uncatalogued). F. CMNFV 46768. G, H. exhibit specimen at Museo Paleontológico Egidio Feruglio museum, Trelew, Argentina. I. exhibit specimen at Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” museum, Buenos Aires, Argentina. J. exhibit specimen at Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” museum, Buenos Aires, Argentina. K, L. exhibit specimen at The Natural History Museum (NHMUK), London, United Kingdom.

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Supplementary Figure S3. Patella in representative modern mammals. A. *Marmota monax* (woodchuck, rodent). B. *Sciurus carolinensis* (Eastern grey squirrel, rodent). C. *Lepus americanus* (snowshoe hare, lagomorph). D. *Felis catus* (domestic cat, feline carnivore). E. *Canis familiaris* (domestic bulldog, canine carnivore). F. *Phoca vitalina* (harbor seal, pinniped carnivore). G. Suborder *Vermilingua sp.* (anteater, pilose xenarthran). H. *Erinaceus sp.* (hedgehog, eulipotyphlan). I. *Dasypus novemcinctus* (nine-banded armadillo, cingulate xenarthran). J. *Loris lydekkerianus* (grey slender loris, primate). K. *Ursus maritimus* (polar bear, ursine carnivore). L. *Bison bison* (American bison, artiodactyl). M. *Ovibos moschatus* (muskox, artiodactyl). N. *Cervus canadensis* (wapiti, artiodactyl). O. *Alces alces* (moose, artiodactyl). P. *Antilocapra americana* (pronghorn, artiodactyl). Q. *Giraffa camelopardalis* (giraffe, artiodactyl). R. *Rhinoceros unicornis* (Indian rhinoceros, perissodactyl). S. *Hippopotamus amphibius* (artiodactyl), neonatal specimen (with well ossified patella). T. *Tragulus javanicus* (chevrotain, artiodactyl). U, V. *Macropus* sp. (kangaroo, Diprotodontidae, Marsupialia) with possible ossified patellae. W, X. *Onychogalea fraenata* (wallaby, Diprotodontidae, Marsupialia) with possible fibrocartilaginous patellae. Y, Z. *Thylacinus cynocephalus* (thylacine, Thylacinidae, Marsupialia) with possible fibrocartilaginous patellae. Specimen numbers (CMNMA = Canadian Museum of Nature, mammal collection): A. CMNMA 32245. B. CMNMA 11793. C. CMNMA 11795. D. CMNMA (uncatalogued). E. CMNMA 32033. F. CMNMA 32190. G. CMNMA 31911. H. CMNMA 31848. I. CMNMA 31920. J. CMNMA 31894. K. CMNMA (uncatalogued). L. CMNMA 1896. M. CMNMA (uncatalogued). N. CMNMA 1894. O. CMNMA 4850. P. CMNMA (uncatalogued). Q. CMNMA 52859. R. CMNMA 52862. S. on exhibit at Galeries d'Anatomie comparée et de Paléontologie, Paris, France. T. on exhibit at the University Museum of Zoology, Cambridge, United Kingdom. U, V. on exhibit at Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” museum, Buenos Aires, Argentina. W, X. on exhibit at the University Museum of Zoology, Cambridge, United Kingdom. Y, Z. on exhibit at the University Museum of Zoology, Cambridge, United Kingdom.

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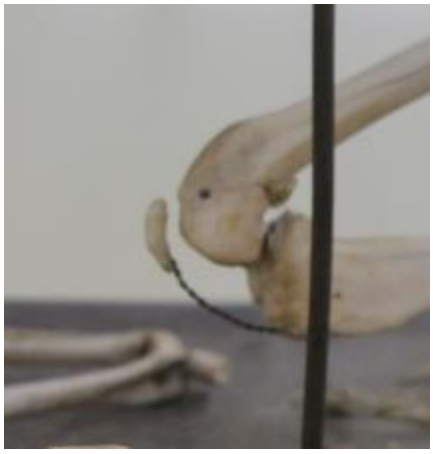

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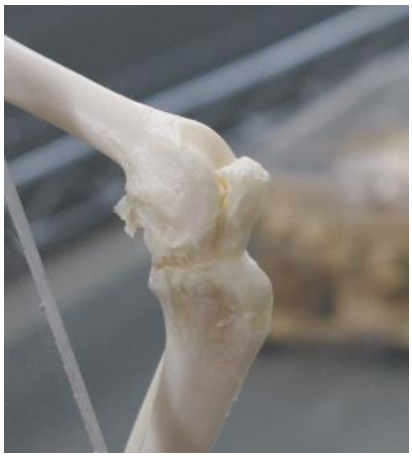

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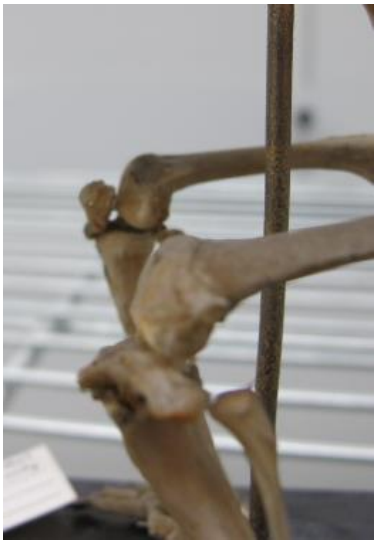

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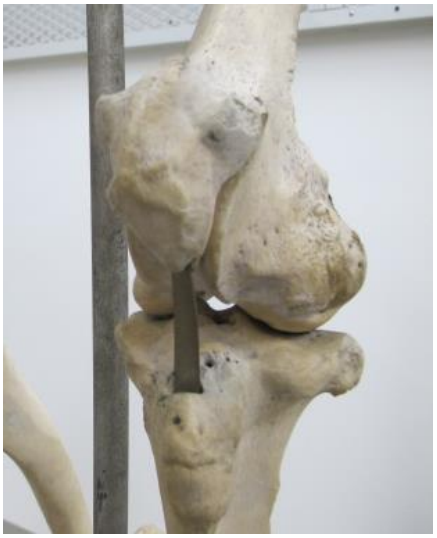

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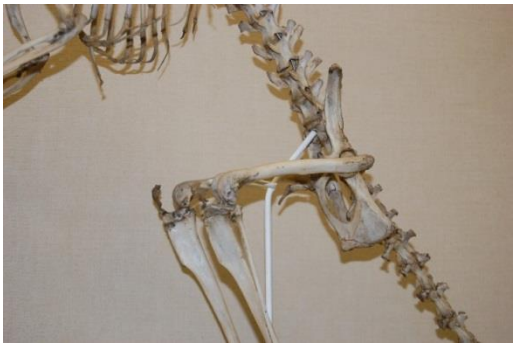

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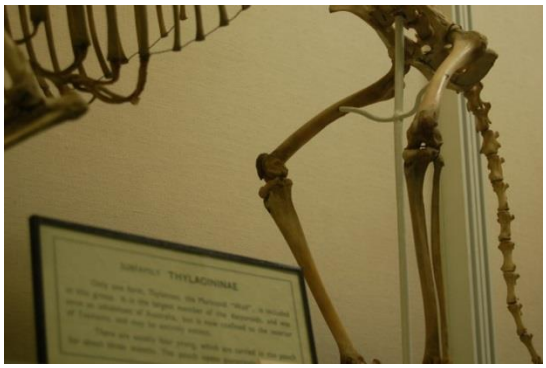
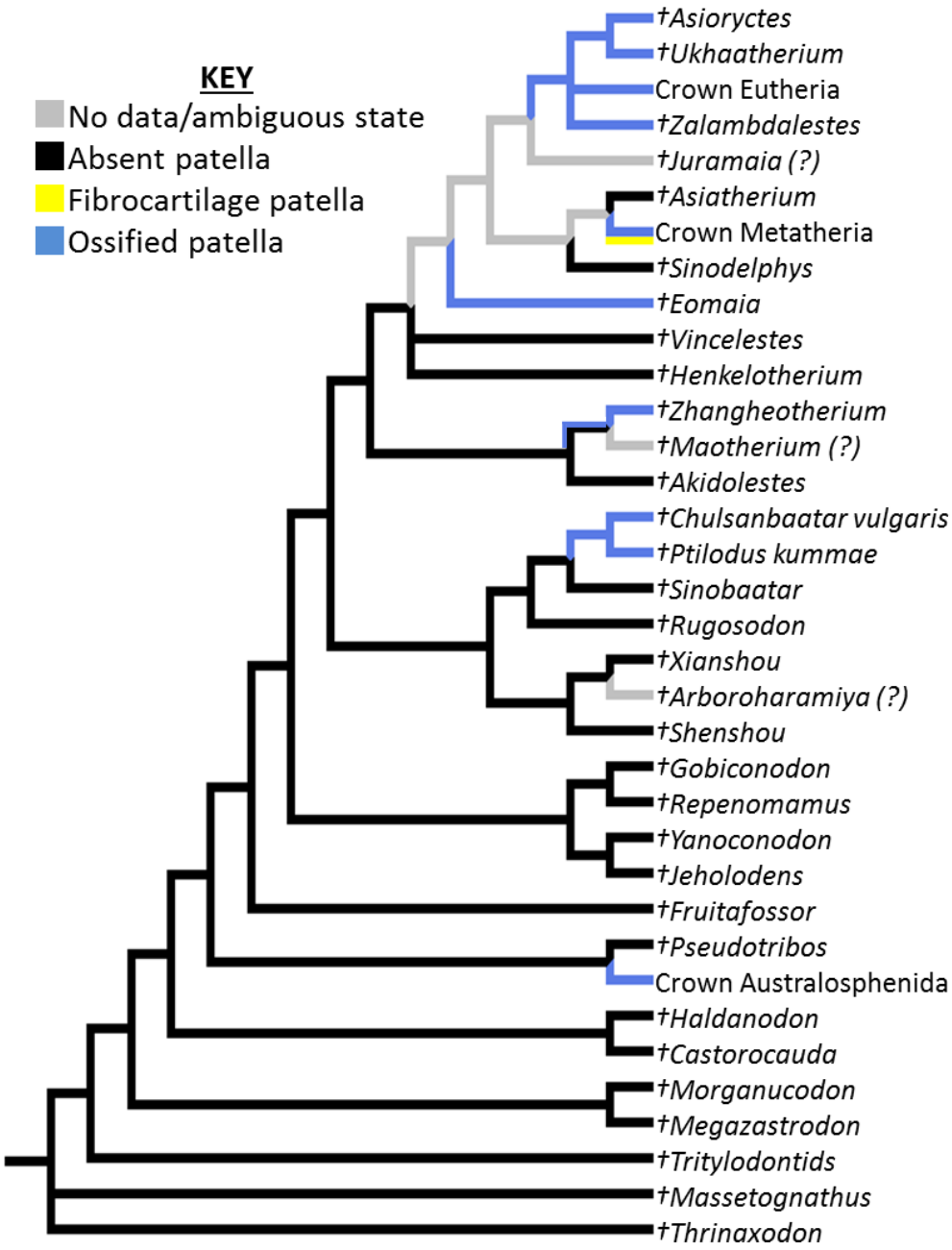
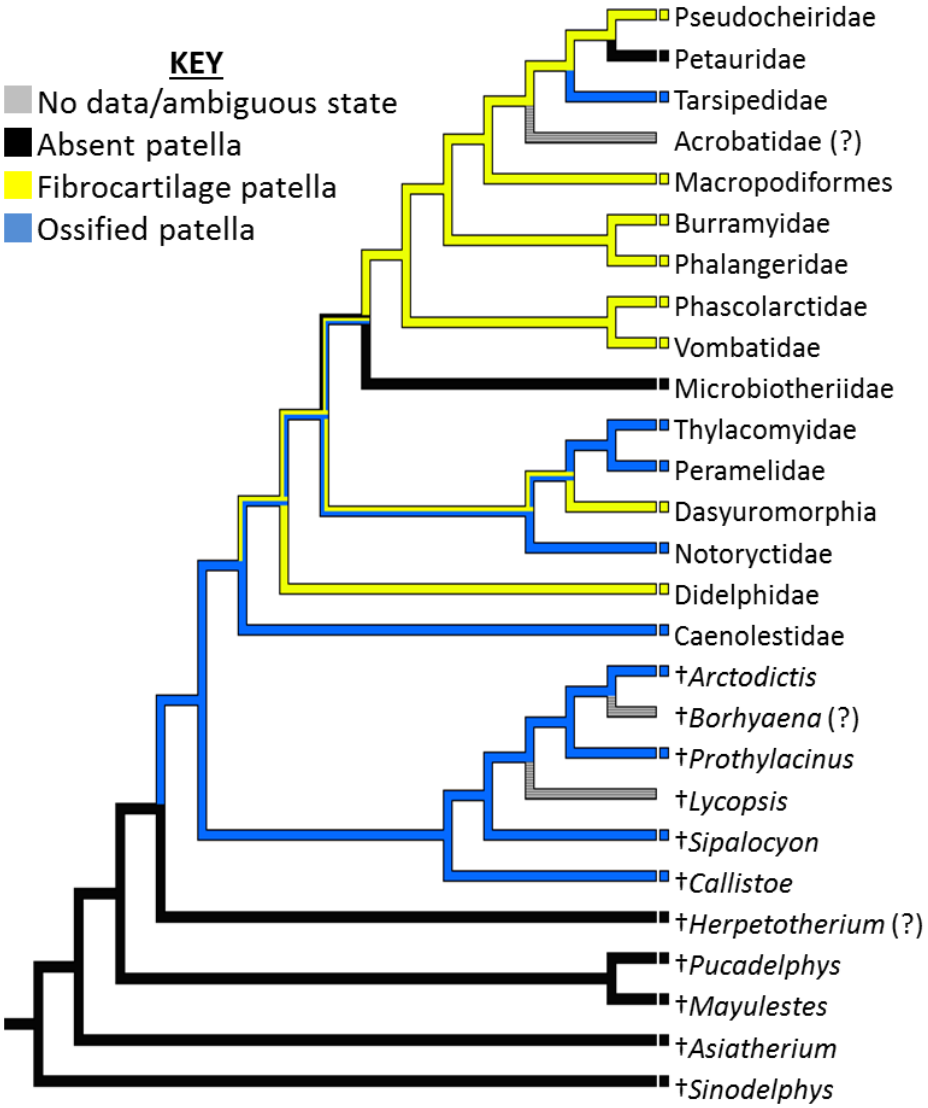


Supplementary Figure S4. Reconstruction of ancestral patellar state in Mesozoic mammals, using Mesquite's parsimony algorithm and ordered character states (unordered states yields an almost identical result), where 0 (black) = absent patella, 1 (yellow) = soft tissue (i.e. fibrocartilaginous in adults) patella, and 2 (blue) = ossified patella. Uncertain patellar state is indicated by grey branches and question mark (?) following taxon name. The tree includes key fossils with hindlimb material (denoted by †), and the topology is based on (O'Leary, Bloch, Flynn *et al.*, 2013a). This reconstruction suggests between 4-6 instances of bony patella evolution; compare vs. Figure 5.



Supplementary Figure S5: Reconstruction of ancestral patellar state in Metatheria, using Mesquite's parsimony algorithm and unordered character states, where 0 (black) = absent patella, 1 (yellow) = soft tissue (i.e. fibrocartilaginous in adults) patella, and 2 (blue) = ossified patella. Uncertain patellar state is indicated by grey branches and question mark (?) following taxon name. The tree includes key fossils with hindlimb material (denoted by †), and the topology is based on (May-Collado, Kilpatrick & Agnarsson, 2015). This reconstruction suggests one instance of bony patella evolution. Compared to Figure 6, there are more internodes of ambiguous character state (i.e. equally parsimonious between states 1 and 2), which could mean a different number of bony patellar loss/re-gain. Note that several very large modern clades with a fibrocartilaginous patella (*e.g.* Macropodiformes, Vombatidae, *etc*.) are collapsed and include many more individual species than the expanded clades with a documented ossified patella.



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