

Online resource 5: phylogenetic analyses

Paleobiology of *Argyrolagus* (Marsupialia, Argyrolagidae): an astonishing case of bipedalism among South American mammals.

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María Alejandra Abello¹ and Adriana Magdalena Candela²

¹Facultad de Ciencias Naturales y Museo (UNLP), Laboratorio de Sistemática y Biología Evolutiva (LASBE), Unidades de investigación Anexo Museo, La Plata, Argentina. Av. 60 y 122. B1900FWA, La Plata, Argentina. Tel. 221 422-8451 int. 140. mabello@fcnym.unlp.edu.ar

²Facultad de Ciencias Naturales y Museo (UNLP), División Paleontología de Vertebrados, Museo de La Plata, La Plata, Argentina. acandela@fcnym.unlp.edu.ar

Morphological matrix

Morphological matrix (Online resource 4) corresponds to that morphological Matrix B of Beck (2017) where *Epidolops* was scored assuming that the Type II petrosals described by Ladevèze (2004) and the IMG VII calcanea described by Szalay (1994) belong to this taxon (see discussion in Beck, 2017).

The following characters were considered additive as proposed by Beck (2017; original character numbers are in brackets): 9400 (4), 9407 (11), 9409 (13), 9415-9416 (19-20), 9422 (26), 9431 (35), 9435-9437 (39-41), 9439 (43), 9442 (46), 9457 (61), 9459 (63), 9480 (84), 9483-9484 (87-88), 9487 (91), 9492 (96), 9504-9505 (108-109), 9508-9509 (112-113), 9515 (119), 9517-9519 (121-123), 9524 (128), 9529 (133), 9535 (139), 9540-9544 (144-148), 9547 (151), 9553 (157), 9555-9556 (159-160), 9558 (162), 9561-9562 (165-166), 9577-9578 (181-182), 9583 (187), 9594 (198), 9597 (201), 9601 (205), 9611 (215), 9630 (234), and 9657 (261).

In the process of scoring *Palaeothentes*, *Proargyrolagus* and *Argyrolagus*, we made some changes to the original codings, based on personal observations and in the descriptions and figures presented by Sánchez-Villagra and Kay (1997), Sánchez-Villagra (2001) and Forasiepi et al (2014). Original character number and codification are in brackets. The scoring changes are the following:

Character 9431 (35): Coracoid process separate and large (0); hook-like process (1); small process (2); small protuberance or absent (3).

Argyrolagus = 3 (previously coded ?)

Character 9438 (42): humerus, medial relief for teres major m. absent (0); present (1).

Palaeothentes = 0 (previously coded ?)

Argyrolagus = 1 (previously coded ?)

Character 9439 (43): humerus, lateral ridge absent (0); ridge or crest (1); massive crest continuous with deltopectoral crest (2).

Palaeotheres = 1 (previously coded ?)

Argyrolagus = 2 (previously coded ?)

Character 9440 (44): humerus, capitulum for radius spherical (0); cylindrical (1).

Argyrolagus = 1 (previously coded ?)

Character 9442 (46): humerus, olecranon fossa or foramen absent (0); small fossa (1); large fossa (2); foramen (3)

Palaeotheres = 2-3 (previously coded 3)

Character 9444 (48): humerus, greater tuberosity height relative to humeral head height equal or greater tuberosity is lower (0); greater tuberosity is higher (1).

Palaeotheres = 0 (previously coded ?)

Character 9447 (51): humerus, proximal extension of capitulum and trochlea longer proximal extension of trochlea (0); equal (1).

Argyrolagus = 1 (previously coded ?)

Character 9449 (53): humerus distal end size small (0); large (1).

Palaeotheres = 0 (previously coded ?)

Character 9450 (54): humerus, head shape symmetrical/ovoid (0); mediolaterally compressed (1).

Palaeotheres = 0 (previously coded ?)

Argyrolagus = 0 (previously coded ?)

Character 9451 (55): humerus, capitulum lateral extension absent (0); present (1).

Argyrolagus = 1 (previously coded ?)

Character 9452 (56): humerus, shaft curvature straight (0); curved (1).

Argyrolagus = 1 (previously coded ?)

Character 9453 (57): ulna, proximal epiphysis, distal most portion of articular surface for humerus ulnar area is less than 1/2 of radial one (0); more (1).

Argyrolagus = 1 (previously coded ?)

Character 9466 (70): tuberosity for rectus femoris m. no relief (0); protuberance (1); depression (2).

Argyrolagus = 1 (previously coded ?)

Character 9472 (76): mediolateral constriction in greater trochanter of femur absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9475 (79): fibula proximal medial accessory shelf absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9476 (80): fibula proximal posterior extension beyond the area of contact with the tibia does not extend posteriorly (0); extends (1).

Argyrolagus = 0 (previously coded ?)

Character 9477 (81): fibula lateral distal process absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9483 (87): tibia proximal dimensions larger mediolaterally than anteroposteriorly (0); equal (1); smaller mediolaterally than anteroposteriorly (2).

Argyrolagus = 2 (previously coded ?)

Character 9489 (93): astragalonavicular facet extends on ventromedial area of head absent (0); present (1).

Argyrolagus = 1 (previously coded ?)

Character 9494 (98): astragalus, relative width of head and neck narrower or as wide as head (0); neck wider than head (1).

Argyrolagus = 1 (previously coded ?)

Character 9502 (106): medial astragalotibial facet, posterior extent does not reach posterior edge of lateral astragalotibial facet (0); equal in anteroposterior length as lateral astragalotibial facet (1).

Argyrolagus = 1 (previously coded ?)

Character 9504 (108): calcaneal sustentacular facet on sustentaculum no sustentaculum (facet is located in calcaneal body) (0); on sustentaculum (1); facet is located above level of sustentaculum, which becomes the medial process (2).

Argyrolagus = 2 (previously coded 1)

Character 9505 (109): ectal facet longest dimension anteromedial to posterolateral (0); straight (1); posteromedial to anterolateral (2).

Argyrolagus = 1 (previously coded ?)

Character 9506 (110): ectal facet longest axis when straight sagittally longer (0); transversely longer (1).

Argyrolagus = 0 (previously coded ?)

Character 9512 (116): calcaneal sustentacular facet anteroposterior convexity concave or flat (0); convex (1).

Argyrolagus = 0 (previously coded ?)

Character 9521 (125): calcaneum accessory facet anterior to sustentacular facet absent (0); present (1).

Argyrolagus = 1 (previously coded 0)

Character 9522 (126): cuboid medial plantar process forms groove absent (0); present (1).

Argyrolagus = 1 (previously coded 0)

Character 9529 (133): navicular size navicular half to one third the size of the cuboid (0); navicular more than half the size of the cuboid to equal to it (1); navicular larger than the cuboid (2).

Argyrolagus = ? (previously coded 1-2)

Character 9546 (150): paracone and metacone placement in M2 medial or buccal (0); buccal margin (1).

Argyrolagus = 0 (previously coded ?)

Proargyrolagus = 0 (previously coded ?)

Character 9551 (155): metaconule absent or not-well developed (0); well-developed or enlarged (1).

Argyrolagus = 0 (previously coded ?)

Character 9560 (164): hypoconulid absent or present absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9565 (169): bunolophodonty or lophodonty developed no (0); yes (1).

Argyrolagus = 0 (previously coded ?)

Proargyrolagus = 0 (previously coded ?)

Character 9566 (170): selenodonty developed no (0); yes (1).

Argyrolagus = 0 (previously coded ?)

Proargyrolagus = 0 (previously coded ?)

Character 9569 (173): Width of frontals versus width of parietals parietal wider or equal to frontal (0); parietal narrower than frontal (1).

Palaeothentes = 0 (previously coded ?)

Argyrolagus = 0 (previously coded ?)

Character 9572 (176): bones surrounding infraorbital canal in the orbit maxilla + lacrimal (0); maxilla only (1).

Argyrolagus = 0 (previously coded ?)

Character 9573 (177): Posterior-most point of premaxillo-nasal contact anterior or at the canine (0); posterior to the canine (1).

Argyrolagus = 1 (previously coded ?)

Character 9574 (178): maximum maxilla (palatal portion) length/width ratio ratio less or equal to 1.5 (0); ratio larger than 1.5 (1).

Argyrolagus = 0 (previously coded ?)

Character 9575 (179): Maxillofrontal contact absent (0); present (1).

Argyrolagus = 1 (previously coded ?)

Character 9576 (180): lacrimal tubercle absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9577 (181): Alisphenoid tympanic wing absent (0); poorly developed (1); moderately developed (2); well-developed, extending to or near posterior lacerate foramen and paroccipital process (3).

Proargyrolagus = 3 (previously coded 2)

Character 9578 (182): Ectotympanic shape ring-shaped (0); moderately broadened (1); tubelike (2).

Proargyrolagus = 0 (previously coded ?)

Character 9579 (183): postglenoid process absent (0); present (1).

Argyrolagus = 0 (previously coded ?)

Character 9585 (189): Size of incisura tympanica narrow or absent (0); wide (1).

Argyrolagus = 1 (previously coded ?)

Character 9586 (190): Foramen ovale position lamina obturans / other bones (0); alisphenoid / petrosal (1); just alisphenoid (2); alisphenoid / squamosal (3).

Palaeothentes = 2 (previously coded ?)

Character 9587 (191): Carotid foramen position in basisphenoid (0); basisphenoid / basioccipital suture (1); basisphenoid / petrosal (2).

Palaeothentes = 0 (previously coded ?)

Character 9589 (193): transverse canal position anterior to carotid foramen (0); perforating pterygoid fossa (1); confluent with carotid foramen (2); posterior to carotid foramen (3).

Argyrolagus = ? (previously coded 1)

Character 9593 (197): septomaxilla absent (0); present (1).

Palaeothentes = ? (previously coded 0)

Proargyrolagus = ? (previously coded 0)

Character 9594 (198): palatal vacuities absent or just small foramina (0); present, restricted to palatine bones (1); present in both palatine and maxillary bones (2).

Proargyrolagus = ? (previously coded 2)

Character 9596 (200): minor palatine foramen absent (0); present (1).

Palaeothentes = 1 (previously coded ?)

Character 9632 (236): inferior petrosal sinus intrapetrosal (0); between petrosal, basisphenoid and basioccipital (1); endocranial (2).

Argyrolagus = ? (previously coded 1)

Character 9633 (237): mastoid exposure contacts the parietal (0); does not contact the parietal (1); greatly reduced, forming a dorsoventrally narrow band on the ventrolateral corner of the posterior face of the cranium (2).

Argyrolagus = ? (previously coded 0-1)

Character 9635 (239): caudal tympanic process of petrosal (1) absent (0); present (1).

Argyrolagus = ? (previously coded 1)

Character 9637 (241): petrosal plate absent (0); present (1).

Argyrolagus = ? (previously coded 0)

Character 9652 (256): posterior cingulid on lower molars absent (0); present (1).

Palaeothentes = 0 (previously coded ?)

Argyrolagus = 0 (previously coded ?)

Character 9658 (262): glenoid fossa planar (0); with distinct articular eminence and mandibular fossa (1); convex (2).

Proargyrolagus = ? (previously coded 0)

Character 9663 (267): antorbital fossa absent (0); present (1).

Argyrolagus = 1 (previously coded ?)

Character 9664 (268): maxillo-nasal contact present (0); prevented by premaxilla-frontal contact (1).

Argyrolagus = 0 (previously coded ?)

Table 1. Summary of unambiguous morphological synapomorphies for selected nodes from the analysis of the combined and morphological matrices. See below for description of character number and states.

Analysis of combined matrix (excluding *Djartia*; see Fig. 6a of main text)

Node	Character	Change
Peramelemorphia+Argyrolagidae	9448	1-> 0
	9476	1 -> 0
	9488	1 -> 0
	9498	1 -> 0
	9502	0 -> 1
	9505	0 -> 1
	9592	0 -> 1
	9663	0 -> 1
Argyrolagidae	9556	2-> 1
	9559	0 -> 1
	9562	0 -> 1
	9577	2 -> 3
	9656	0-> 1
	9657	0 -> 1
	9667	0-> 1
<i>Argyrolagus</i> + <i>Microtragulus</i>	9551	1 -> 0
	9556	1 -> 0
	9560	1 -> 0
	9562	1 -> 2
	9657	1 -> 2

Analysis of morphological matrix (see Fig. 6b of main text)

Node	Character	Change
Peramelemorphia+Argyrolagidae	9488	1-> 0
	9502	0 -> 1
	9521	0 -> 1
	9525	1 -> 0
	9592	0 -> 1
	9663	0 -> 1
Argyrolagidae	9577	2-> 3
	9656	0 -> 1
	9657	0 -> 1

	9667	0 -> 1
<i>Argyrolagus+Microtragulus</i>	9551	1 -> 0
	9554	1 -> 0
	9556	1 -> 0
	9560	1 -> 0
	9562	1 -> 2
	9657	1 -> 2

Morphological character list

9448. Humerus, medial epicondyle size small (0); large (1).
9476. Fibula proximal posterior extension beyond the area of contact with the tibia does not extend posteriorly (0); extends (1).
9488. Astragalonavicular facet extends on medial side of head absent (0); medial (1).
9498. Ectal facet major dimension orientation straight (0); posteromedial to anterolateral (1).
9502. Medial astragalotibial facet, posterior extent does not reach posterior edge of lateral astragalotibial facet (0); equal in anteroposterior length as lateral astragalotibial facet (1).
9505. Ectal facet longest dimension anteromedial to posterolateral (0); straight (1); posteromedial to anterolateral (2)
9521. Calcaneal sustentacular facet anterior edge anterior to posterior facet (0); equal or posterior to posterior facet (1).
9525. Calcaneum sustentacular facet reaches anterior end absent (0); present (1).
9551. Paraconid on lower molars absent (0); present (1).
9554. P1 absent (0); reduced and single-rooted (1); present, well-developed (2).
9556. Upper P2 absent (0); greatly reduced (1); present (2).
9559. Procumbent gliriform lower anteriormost incisor absent (0); present (1).
9560. Hypoconulid absent or present absent (0); present (1).

9562. Upper canine caniniform or premolariform (0); very small (1); absent (2).
9577. Alisphenoid tympanic wing absent (0); poorly developed (1); moderately developed (2); well-developed, extending to or near posterior lacerate foramen and paroccipital process
9592. Shape of nasals posteriorly expanded (0); not posteriorly expanded (1).
9656. Retrodental foramen absent (0); present (1).
9657. Molars non-hypsodont (0); hypsodont (1); hypselodont (2).
9663. Antorbital fossa absent (0); present (1).
9667. P3 morphology premolariform (0); hypsodont or hypselodont (1); blade-like (2).

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