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Supplementary information

Evolution of terrestrial anatomy revealed by a derived stem tetrapod

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TITLE

AUTHORS

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Part 1. Systematic Palaeontology

TETRAPODOMORPHA Ahlberg, 1991

STEGOCEPHALI Cope, 1868

Genus *WESTLOTHIANA* Smithson & Rolfe, 1990

Type species. *Westlothiana lizziae* Smithson & Rolfe, 1990

Holotype. National Museums of Scotland NMS.G.1990.72.1, slab and counterslab. A nearly complete, mostly articulated skeleton.

Locality and Horizon. From Unit 82 of the East Kirkton Limestone[29], of the East Kirkton Quarry, near Bathgate, West Lothian, 17 miles west of Edinburgh, Scotland[58]. The East Kirkton Limestone is within the West-Lothian Oil-Shale Formation, which can be assigned to Holkerian-Arundian age[59,169].

Revised Diagnosis. Overall length under 200mm. Skull table and temporal region plesiomorphic: skull has broad parietal bones, tabular and supratemporal form posterolateral corner of skull. Postparietal, tabular and supratemporal all restricted to skull table, and tabular bears a short tabular horn. Parietals contact tabulars but not squamosals. Orbits are large with an encompassing ring of sclerotic plates, postfrontal large and extends almost to the front of orbit, contacting prefrontal. Lacrimal has a dorsal orbital process. Prefrontal elongate, extending to external naris and contacting premaxilla. Premaxilla with concave medial margins for an internarial fenestra. Vomer elongate and bulbous anteriorly as in early tetrapods, framing a midline palatal fenestra. Palatine deeply incised to accommodate internal naris. Plesiomorphic palatal dentition; palate is almost entirely denticulate, including parasphenoid plate and quadrate ramus of pterygoid. Fang pairs present on vomer and palatine but not ectopterygoid. Ectopterygoid is large, so near equal in size to palatine. Pterygoid lacks amniote-like transverse flange. Quadrate lacks a dorsal process. Orbitosphenoids extend the length of the cultriform process. Basicranial fissure present between parabasisphenoid and basioccipital. Mandible extremely denticulate, with shagreen present on the adsymphyseal, all three coronoids, prearticular, and even articular. Atlas lacks odontoid process, atlas anterior and posterior articulating surfaces equal in width, atlas neural arch unfused to centrum. 36 gastrocentrous presacral vertebrae. Neural arches sutured to centra, wedge-shaped intercentra, ribs extend for length of presacral vertebral column. Limbs reduced and particularly small relative to trunk. Forelimbs approximately half the size of hindlimbs, humerus clearly waisted and with supinator process, large pelvis with long puboischiadic plate, slender femur with only very moderately expanded proximal and distal ends. Four proximal tarsals in which the tibiale is significantly smaller than the rest, five distal tarsals, and five digits on the pes. Pes phalangeal formula 2, 3, 4, 5, 4. Thick, overlapping dorsal scales and thin, narrow, oblong ventral scales.

Remarks. When originally described, NMS. G.1991.47.1 was referred to *Westlothiana lizziae.* Here, we unrefer this specimen to the taxon *Westlothiana lizziae*. The two specimens are from different units of the East Kirkton Limestone. However, during the original research little was known about the postcranial morphology of the holotype, and most similarities used to assign this specimen to *Westlothiana* could represent tetrapod plesiomorphies. Now that more detail of the holotype is known, substantial differences can be noted between the two specimens, including the differing numbers of vertebrae, and the differing components making up the foot. We deem that these features are highly unlikely to be ontogenetic, and therefore NMS. G.1991.47.1 should not be referred to *Westlothiana* pending further examination.

Part 2. Specimens and literature examined

Taxon name	Specimens studied	Reference(s)
Acanthostega gunnari		Coates, 1996[114]; Porro et al. 2015a[115]
Acherontiscus caledoniae	NMS G.1967.13.1	Carroll, 1969[33]; Clack et al, 2019[95]
Adelogyrinus simorhynchus		Andrews & Carroll, 1991[82]
Aerosaurus wellesi	UCMP 40096, 35762, 40097	Langston & Reisz, 1981[76]
Anthracosaurus russelli		Panchen, 1977[74]
Araeoscelis gracilis	MCZ 4380	Reisz et al, 1984[89]
Archaeovenator hamiltonensis	KUVP 12483	Reisz & Dilkes, 2003[60]
Archeria crassidisca	AMNH 4550, MCZ 2045, 2047	Holmes, 1989[32]
Ariekanerpeton sigalovi		Klembara & Ruta, 2005[103]
Asaphestera intermedia		Carroll & Gaskill, 1978[30,] Mann et al. 2020
Balanerpeton woodi	GLAHM V205, UMZC T131, NMS G 1985 4.1, NHMUK R12014	Milner & Sequeira, 1993[80]
Baphetes sp.		Beaumont, 1977[90]; Milner & Lindsay, 1998[116]
Belebey vegrandis	GU 104/B-2020, SGU 104/B-2021	Reisz et al, 2007[117]
Brachydectes newberryi	AMNH FARB 6941, USNM V 4509, USNM V 4477	Pardo & Anderson, 2016[97]; Wellstead, 1991[109]
Caerorachis bairdi		Ruta et al, 2001[42]
Captorhinus aguti	AMNH 4333, KUVP 9978, USNM PAL 606433, 619436, 619437, 619440_3	Fox & Bowman, 1966[40]
Cardiocephalus sp.	AMNH FARB 3892	Carroll & Gaskill, 1978[30]
Casea broilii	FMNH UC 656, 698, 1011	Olson et al, 1968[67]
Chroniosaurus dongusensis	THUg 3308, PIN 3585/124, PIN 105B/1097	Clack & Klembara, 2009[86]
Dendrerpeton helogenes	NSM 987 GF 99.1	Arbez et al, 2022[81]
Diadectes abistus	FM UC 1075/675	Berman et al, 1998[61]
Dimetrodon sp.	AMNH FARB 2275, 4081, 25888, 25886, 25884, 25860, FMNH UC 114; 540; 804; 813; 1001	Romer et al, 1940[75]
Discosauriscus austriacus	UMZC 2000.11 R37612	Klembara, 1997[62]; Klembara & Bartik, 1999[102]
Diplocaulus sp.	AMNH 23175, and others in AMNH collection	Douthitt, 1917[77]

Diploceraspis sp	MCZ3009	Beerbower, 1963[72]
Doleserpeton annectens		Sigurdsen & Bolt, 2010[108]
Echinerpeton intermedium	RM 206866	Mann & Paterson, 2020[85,] Reisz, 1971
Edaphosaurus boanerges	MCZ 1761, 1680; AMNH FARB 7131, 7129, 7128	Modesto, 1995[91]
Edops craigi	AMNH FARB 7614, USNM V 23309, MCZ 1378	Romer & Witter, 1942[118]
Eocasea martini	KUVP 9616b	Reisz & Fröbisch, 2014[87]
Eothyris parkeyi	MCZ 1161	Reisz et al, 2009[68]
Erpetonyx arsenaultorum	ROM 55402	Modesto et al, 2015[119]
Euconcordia cunninghami	KUVP 87102A + B	Reisz et al, 2016[71]
Euryodus sp.	FM UR 2296	Carroll & Gaskill, 1978[30]; Gee et al, 2021[4]
Eusthenopteron sp.		Porro et al. 2015b[120]; Downs et al. 2018[121]
Gephyrostegus bohemicus	UMZC T. 1337	Klembara et al. 2014[35]
Gerobatrachus hottoni	USNM 40971	Anderson et al, 2008[122]
Greererpeton burkemorani	CMNH 10931, USNM V 22576, USNM PAL 419694	Smithson, 1982[73]; Godfrey, 1989[110]
Hapsidopareion lepton	FMNH 2303, 2304, 2305.	Carroll & Gaskill, 1978[30,] Jenkins et al., 2025
Haptodus garnettensis	ROM 14156, 29872, 30099, 43601; 43602: 43608	Laurin, 1993[63]
Huskerpeton englehorni	USNM 32144	Huttenlocker et al, 2013[25]
Hylonomus lyelli	NHMUK R.4168, NHMUK R.4167, NHMUK R.445	Carroll, 1964[70,] and scans of holotype specimen
Hyloplesion longicostatum	NMS G. 1899.32.3	Carroll & Gaskill, 1978[30]
Ianthasaurus hardestii	ROM 59933	Reisz & Berman, 1986[123], Mazierski & Reisz, 2010
Keraterpeton galvani	PV R 8452/8457	Milner, 2018[39]
Lethiscus stocki	MCZ 2185	Pardo et al, 2017[1]; Anderson et al, 2003[43]
Limnoscelis paludis	MCZ 1948	Romer, 1946[65]; Kennedy, 2010[104]
Llistrofus pricei (= *Hapsidopareion*)	FMNH UR 948	Gee et al, 2019[83]
Micraroter erythrogeois	FMNH UR 2311	Carroll & Gaskill, 1978[30]
Microbrachis pelikani	NMS G. 1898.105.26/27	Carroll & Gaskill, 1978[30]
Milleropsis pricei	BP/1/720, and specimens referred by Jenkins et al. 2025	Gow, 1972[88]
Oestocephalus sp.	NMW 1899.IX.13b	Carroll, 1998[36]
Opisthodontosaurus carrolli	OMNH 77469, OMNH 77471, UWBM 89171.	Reisz et al, 2015[66]
Orobates pabsti	MNG 8760 MNG 14257 MNG 8980	Berman et al, 2004[34]

Orovenator mayorum	OMNH 74606 OMNH, 74607	Ford & Benson, 2019[79]
Paleothyris acadiana	MCZ 4381, 4382, 4384	Carroll, 1969[33]
Pantelosaurus saxonicus	RS 14752	Spindler, 2016[98]
Pantylus cordatus	FMUC 1075, FMUC 675, MCZ 2040, UT-4001	Carroll & Gaskill, 1978[30]
Pederpes finneyae		Clack & Finney, 2005[96]
Petrolacosaurus kansensis	KUVP 1424, 8351, 9951, 33607, 33602	Reisz, 1977[38]
Phlegethontia linearis	NMW.1899.IX.13b MCZ2038 (skull/vert) MCZ2204(skull/vert)	Anderson 2002[124], Anderson 2007[125]
Procynosuchus delaharpeae		Kemp, 1979[126]; Kemp & Parrington, 1980[127]
Seymouria sp.	MNG - 772, MCZ 1081, MCZ 1084, FMNH UR 458	Berman et al. 2000[69,] Bazzana et al. 2019
Scincosaurus crassus	Numerous AMNH specimens	Milner & Ruta, 2009[78]
Silvanerpeton miripedes	UMZC T.1317 UMCZ T.1251 UMZC T.1351	Ruta & Clack, 2006[22]
Solenodonsaurus janenschi		Danto et al, 2012[113]
Tiktaalik roseae		Daeschler et al. 2006[128]; Shubin et al. 2006[129]; Downs et al. 2008[130]; Shubin et al. 2014[131]
Tuditanus punctulatus	AMNH FARB 6926	Carroll & Gaskill, 1978[30]
Utaherpeton franklini		Carroll et al, 1991[132]
Varanops brevirostris	FMNH UC 644	Campione & Reisz, 2010[133]
Varanosaurus acutirostris	AMNH FARB 4174 , FMNH PR 167	Bolt & Scott, 1995[64]
Vaughnitis smithae	MCZ 2985	Brocklehurst et al, 2016[84]
Westlothiana lizziae	NMS G.1990.72.1, NMS G.1991.47.1	Smithson et al, 1993[29]
Whatcheeria deltae	FMNH PR 1700, , 1634, 1814	Rawson et al, 2021[41]
Youngina capensis	AMNH 556, BPI/1/70, 2459, 2871, 3859	Gow, 1974[37,] Hunt et al. 2023

Part 3. Character List

The following character list has been created following the characters in a comprehensive list of existing phylogenetic analyses, with examples that originally focused on crown tetrapods, with an emphasis on stem and crown amniotes. This dataset was later expanded upon to incorporate numerous characters regarding early tetrapodomorph anatomy when the plesiomorphic features of *Westlothiana*

became apparent. Some novel characters have also been introduced. Each character is listed with notes on its source, optimisation, and comments on the scoring, interpretive thoughts, and explanations as to the inclusion or modification of the character. Characters in this analysis are denoted by "ch.", while characters in previous analyses are referred to by "c."

The previous analyses from which characters have been taken and modified have been listed below, along with abbreviations that are used to summarise the analyses from this point forward: Brinkman & Eberth, 1983[134] (**BE1983**), Heaton & Reisz, 1986[135] (**HR1986**), Reisz, 1986[136] (**R1986**), Gauthier et al., 1988[14] (**Gea1988**), Carroll & Currie, 1991[137] (**CC1991**), Laurin, 1991[138] (**L1991**), Reisz et al., 1992[139] (**Rea1992**), Laurin, 1993[63] (**L1993**), Modesto, 1994[91] (**M1994**), Berman et al., 1995[64] (**Bea1995**), Laurin & Reisz, 1995[16] (**LR1995**), DeBraga & Rieppel, 1997[93] (**DR1997**), Laurin & Reisz, 1997[17] (**LR1997**), Dilkes, 1998[140] (**D1998**), Laurin et al., 1998[18] (**Lea1998**), Reisz et al., 1998[141] (**Rea1998**), Sidor & Hopson, 1998[142] (**SH1998**), Rieppel, 1999[143] (**R1999**), Berman et al., 2000[69] (**Bea2000**), Anderson, 2001[24] (**A2001**), Reisz & Dilkes, 2003[60] (**RD2003**), Ruta et al., 2003[19] (**Rea2003**), Modesto et al., 2004[144] (Mea2004), Müller, 2004[145] (**M2004**), Maddin et al., 2006[146] (**Mea2006**), Müller & Reisz, 2006[147] (**MR2006**), Tsuji, 2006[148] (**T2006**), Modesto et al., 2007[149] (**Mea2007**), Reisz et al., 2007[117] (**Rea2007**), Ruta & Coates, 2007[20] (**RC2007**), Maddin et al., 2008[150] (**Mea2008**), Reisz et al., 2009[68] (**Rea2009**), Reisz et al., 2010[151] (**Rea2010**), Fröbisch et al., 2011[152] (**F2011**), Nesbitt, 2011[153] (**N2011**), Reisz et al., 2011[154] (**Rea2011**), Benson, 2012[155] (**B2012**), Tsuji et al., 2012[156] (**Tea2012**), Huttenlocker et al., 2013[25] (**Hea2013**), Ezcurra et al., 2014[157] (**Eea2014**), Klembara et al., 2014[35] (**Kea2014**), MacDougall & Reisz, 2014[158] (**MR2014**), Reisz & Fröbisch, 2014[87] (**RF2014**), Modesto et al., 2015[119] (**Mea2015**), Pritchard et al., 2015[159] (**Pea2015**), Schoch & Sues, 2015[160] (**SS2015**), Brocklehurst et al., 2016[84] (**Bea2016**), Clack et al., 2016[161] (**Cea2016**), Ezcurra, 2016[162] (**E2016**), Laurin & Piñeiro, 2017[163] (**LP2017**), Pardo et al., 2017[1] (**Pea2017**), Modesto et al., 2018[164] (**Mea2018**), Clack et al., 2019[95] (**Cea2019**), Marjanovic & Laurin, 2019[26] (**ML2019**), Ford & Benson, 2020[21] (**FB2020**), Ruta et al. 2022 (**RCT2022**) Simões et al., 2022[165] (**Sea2022**), Marsicano et al. 2024[166] (**Mar2024),** Jenkins et al. 2025a[167] (**J2025a),** Jenkins et al. 2025b[168] (**J2025b)**.

1. **Skull length:width ratio: broader than long (0); as long as broad (1); longer than broad (2).**

Cea2016 (c.154), ML2019 (c.95), Cea2019 (c.154), Hea2013 (c.3), Pea2017 (c.3).

Almost all included taxa have a skull that is longer than broad, but some temnospondyls, nectrideans and seymouriamorphs have skulls that are relatively broad. Within temnospondyls, *Doleserpeton* has a skull that is as broad as long (Sigurdsen & Bolt, 2010) and *Gerobatrachus* even has a skull that is broader than long (Anderson et al., 2008). A skull that is broader than long is also present in the microsaur *Pantylus* (Carroll & Gaskill, 1978), diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963), as does *Seymouria* (Berman et al., 2000), whilst other seymouriamorphs have a skull that is as broad as long (Klembara, 1997; Klembara & Ruta, 2005).

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (2 -> 0), *Scincosaurus crassus* (2 -> 1), *Pantylus cordatus* (2 -> 0). ACCTRAN: Seymouriamorpha (2 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (2 ->

0), *Doleserpeton annectens* (0 -> 1). DELTRAN: *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (2 -> 1), *Seymouria sanjuanensis* (2 -> 0), *Doleserpeton annectens* (2 -> 1), *Gerobatrachus hottoni* (2 -> 0).

2. **Ratio of anteroposterior skull length:trunk length: <0.2 (0); 0.2-0.29 (1); 0.3 - 0.45 (2); >0.45 (3). (ordered).**

A2001 (c.182), Hea2013 (c.2), Pea2017 (c.2)

The skull length is measured along the midline from the tip of the premaxillae to the posterior point of the occiput or midline skull table, depending on which occupies the posterior most position, in dorsal view.

Unambiguous: *Westlothiana lizzae* (1 -> 0), Sphenacodontia (1 -> 2), *Edaphosaurus boanerges* (1 -> 0), *Diadectes abistus* (1 -> 2), Seymouriamorpha + *Gephyrostegus bohemicus* (1to3), *Seymouria sanjuanensis* (3 -> 2), *Chroniosaurus dongusensis* (1to3), *Dendrerpeton helogenes* (2 -> 3). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (3 -> 1), Tetrapoda + *Baphetes sp.* (1 -> 2), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1), Diplocaulidae (0 -> 1), *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 3), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (1 -> 2), Captorhinidae (2 -> 3). DELTRAN: Tetrapoda (3 -> 2), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha , *Diplocaulus sp.* (0to3), *Keraterpeton galvani* (0 -> 1), *Captorhinus aguti* (1to3), *Greererpeton burkemorani* (3 -> 1).

3. **Interorbital distance (at narrowest point) relative to maximum anteroposterior orbit diameter: interorbital distance smaller (0); interorbital distance equal (1); interorbital distance larger (2).**

Cea2016 (c.158), Cea2019 (c.158). Modified from Rea2003 (c.103, c.104), RC2007 (c.106, c.107), ML2019 (c.86, c.87).

The minimum distance separating the medial (in dorsal aspect) margins of the orbits is measured.

Unambiguous: *Adelogyrinus symorhynchus* (2 -> 1), *Utaherpeton franklini* (2 -> 0), *Diplocaulus sp.* + *Diploceraspis sp.* (2 -> 1), Aïstopoda (2 -> 0), *Microbrachis pelikani* (2 -> 0), Diadectamorpha (0 -> 2), *Dendrerpeton helogenes* (0 -> 1), *Edops craigi* (0 -> 2), *Baphetes sp.* (0 -> 1), *Greererpeton burkemorani* (0 -> 2). ACCTRAN: .Synapsida (0 -> 1), Edaphosauridae + Sphenacodontia (1 -> 2), *Haptodus garnettensis* (2 -> 0), Seymouriamorpha (0 -> 2), *Discosauriscus austriacus* (2 -> 0). DELTRAN: *Eothyris parkeyi* (0 -> 1), Sphenacodontidae (0 -> 2), *Edaphosaurus boanerges* (0 -> 2), *Ariekanerpeton sigalovi* (0 -> 2), *Seymouria sanjuanensis* (0 -> 2).

4. **Interorbital distance (at narrowest point) relative to half of maximum skull table width: interorbital distance smaller (0); interorbital distance equal (1); interorbital distance larger (2).**

Rea2003 (c.103), RC2007 (c.106), ML2019 (c.86).

The interorbital distance is measured as the shortest straight line between the orbits perpendicular to the anteroposterior axis of the skull. A particularly large interorbital distance is present widely in *Westlothiana* many former "lepospondyls" including *Brachydectes* (Pardo et al., 2016) and several microsaurs (Carroll & Gaskill, 1978), diadectamorphs (Romer, 1946; Berman et al., 1998; 2004), seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005), *Milleretta* (Gow, 1972) and *Edaphosaurus* (Modesto, 1995).

Unambiguous: *Brachydectes newberryi* (0 -> 2), *Tuditanus punctulatus* (0 -> 1), *Asaphestera intermedia* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), *Hapsidopareion lepton* (0 -> 2), *Westlothiana lizzae* (0 -> 2), *Milleropsis pricei* (0 -> 1), Diadectamorpha (0 -> 2), *Seymouria sanjuanensis* (0 -> 2). ACCTRAN: Edaphosauridae (0 -> 2). DELTRAN: *Edaphosaurus boanerges* (0 -> 2).

5. **Preorbital region of skull length:width ratio (preorbital region is defined as the region anterior to a straight line perpendicular to the long axis of the skull, in line with the anteriormost tip of orbits): less than twice as wide as long (0); twice as wide as long (1).**

Cea2016 (c.155), Cea2019 (c.155), A2001 (c.27), LR1997 (c.4), Lea1998 (c.4), Hea2013 (c.36), Pea2017 (c.32).

The preorbital region of the skull becomes relatively short and wide, so that it measures twice as wide as long, in many former "lepospondyls", including the microsaurs *Hyloplesion*, *Microbrachis* and *Pantylus* (Carroll & Gaskill, 1978), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), *Brachydectes* (Pardo et al., 2016) and adelospondyls (Andrews & Carroll, 1991; Clack et al., 2019). This state is also observed in seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005), the temnospondyls *Balanerpeton* (Milner & Sequeira, 1993) and *Doleserpeton* (Sigurdsen & Bolt, 2010) and *Gerobatrachus* (Anderson et al., 2008).

Unambiguous: Aïstopoda + Adelospondylii + *Utaherpeton franklini* (0 -> 1), *Utaherpeton franklini* (1 -> 0), Aïstopoda (1 -> 0), *Pantylus cordatus* (0 -> 1), Seymouriamorpha (0 -> 1). ACCTRAN: Temnospondyli except *Edops craigi* (0 -> 1), *Dendrerpeton helogenes* (1 -> 0). DELTRAN: *Balanerpeton woodi* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1).

6. **Skull, shape of antorbital region: mediolaterally broad, nasal largely dorsal element (0); mediolaterally narrow and dorsoventrally tall, nasal has nearly vertical contribution to snout (1).**

FB2020 (c.2), M1994 (c.9), Rea1998 (c.12), RD2003 (c.12), Mea2006 (c.43), Rea2010 (c.5), B2012 (c.3), Sea2018 (c.4).

A dorsoventrally tall snout, resulting in a predominantly lateral contribution of the nasal to the snout, is present particularly in most synapsids (Romer et al., 1940; Laurin, 1993; Bolt & Scott, 1995; Modesto, 1995; Campione & Reisz, 2010; Spindler, 2016), although the condition is not found in Caseasaurs, in which the skull is not dorsoventrally tall (Olson et al., 1968; Reisz et al., 2009; Brocklehurst et al., 2016). A tall snout is, however, observed in a variety of other disparate taxa including *Whatcheeria* (Rawson et al., 2021), and the nasal is positioned quite vertically in microsaurs (Carroll & Gaskill, 1978).

Unambiguous: *Acherontiscus caledoniae* (1 -> 0), Nectridea (1 -> 0), Synapsida (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), *Archaeovenator hamiltonensis* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0). DELTRAN: *Whatcheeria deltae* (0 -> 1).

7. **Nature of dermal sculpturing: no ornamentation or sculpture (0); sculpturing in pits or grooves (1).**

LR1997 (c.3), Lea1998 (c.3), A2001 (c.47), Cea2016 (c.170), Cea2019 (c.170), Hea2013 (c.65). Modified from Pea2017 (c.59, c.344 and c.345)

A variety of taxa from across various clades show different levels of dermal sculpture. In order to score as state 1, the dermal sculpturing must consist of clear pits or grooves across most of the dermal skull elements. For example, whilst there are a small number of pits on the dentary of *Westlothiana*, as these are restricted to the anterior tip of the mandible it is scored as state 0.

Unambiguous: (1 -> 0), Nectridea (0 -> 1), *Oestocephalus sp.* (0 -> 1), *Huskerpeton englehorni* (1 -> 0), Caseidae (0 -> 1), *Euconcordia cunninghami* (0 -> 1), *Diadectes abistus* (1 -> 0), *Whatcheeria deltae* (1 -> 0), *Discosauriscus austriacus* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), Diadectamorpha (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Westlothiana lizziae* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Solenodonsaurus janenschi* (1 -> 0), *Doleserpeton annectens* (1 -> 0).

8. **Lateral line canals in adults: absent (0); present (1).**

A2001 (c.46), Hea2013 (c.64), Pea2017 (c.58). Modified from a division of LR1997 (c.1), Lea1998 (c.1), Rea2003 (c.115), RC2007 (c.120), ML2019 (c.100).

Lateral line sensory canals are present in stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) including the embolomere *Anthracosaurus* (Panchen, 1977) as well as crown tetrapods including the microsaurs *Asaphestera* and *Microbrachis* (Carroll & Gaskill, 1978) and diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018).

Unambiguous: Tetrapoda (1 -> 0), Adelospondyli (0 -> 1), Diplocaulidae (0 -> 1), *Microbrachis pelikani* (0 -> 1), *Asaphestera intermedia* (0 -> 1), *Anthracosaurus russelli* (0 -> 1).

9. **Lateral line canal enclosure: entirely within grooves (0); partially in grooves, partially enclosed (1); entirely enclosed (2); lateral line canals absent (inapplicable).**

Modified from a division of LR1997 (c.1), Lea1998 (c.1), Rea2003 (c.115), RC2007 (c.120), ML2019 (c.100).

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 0), Embolomeri (0 -> 2). DELTRAN: *Acherontiscus caledoniae* (1 -> 2), Synapsida (1 -> 0), *Anthracosaurus russelli* (1 -> 2), *Baphetes sp.* (1 -> 0).

10. **Mandibular sensory canal: absent (0); present (1).**

Cea2016 (c.134), Cea2019 (c.134), Pea2017 (c.306).

A mandibular sensory canal is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and other stem tetrapod taxa (Smithson, 1981) along with the microsaur *Microbrachis* (Carroll & Gaskill, 1978) and the nectridean *Diplocaulus* (Douthitt, 1917).

Unambiguous: Adelospondyli (0 -> 1), *Diplocaulus sp.* (0 -> 1), *Microbrachis pelikani* (0 -> 1), *Asaphestera intermedia* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 0), Embolomeri. DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha(1 -> 0), Temnospondyli (1 -> 0).

11. **Posterior skull margin: concave (0); straight (1); convex (2); undulating (3).**

ML2019 (c.43, c.69), Hea2013 (c.34), Pea2017 (c.30). Modified from FB2020 (c.5)

There is a wide and complicated distribution of states of this character, although scoring is straightforward and done in dorsal view. This character does not incorporate Ford and Benson (2020) c.5, which concerns a bilateral embayment of the skull, and is considered to be a reptile synapomorphy. A reptile-like bilateral embayment is only scored as state 3 if it gives the skull an overall undulating margin, as it does in *Petrolacosaurus*, in which the

posterior peak of the midline skull, in between the embayment, approaches a similar distance posteriorly as the lateral corners of the skull (Reisz, 1977). There are, however, taxa in which there is a small bilateral embayment, but the overall dominant shape of the posterior margin is concave, and as such should be scored as state 0, such as *Archaeovenator* (Reisz & Dilkes, 2003) and *Orovenator* (Ford & Benson, 2019). This is covered further in ch.120.

Unambiguous: Tetrapoda + *Baphetes sp.* (3 -> 0), *Cardiocephalus sp.* (1 -> 2), *Micraroter erythrogeois* (1 -> 2), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 2), *Procynosuchus delaharpeae* (0 -> 3), Araeoscelidia (0 -> 3), *Ariekanerpeton sigalovi* (0 -> 1), *Silvanerpeton miripedes* (0 -> 1). ACCTRAN: *Acherontiscus caledoniae* (3 -> 2), Nectridea (3 -> 0), *Scincosaurus crassus* (0 -> 1), *Lethiscus stocki* + *Phlegethontia linearis* (3 -> 1), *Tuditanus punctulatus* (1 -> 0), *Asaphestera intermedia* (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 3), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (3 -> 0), *Hylonomus lyelli* (3 -> 1), Temnospondyli except *Edops craigi* (0 -> 1), *Dendrerpeton helogenes* (1 -> 0).. DELTRAN: *Acherontiscus caledoniae* (1 -> 2), *Adelogyrinus simorhynchus* (1 -> 3), *Brachydectes newberryi* (1to3), Diplocaulidae (1 -> 0), *Oestocephalus sp.* (1 -> 3), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (0 -> 1), *Westlothiana lizziae* (0 -> 1), *Belebey vegrandis* (0 -> 1), *Euconcordia cunninghami* (0 -> 3), *Hylonomus lyelli* (0 -> 1), *Paleothyris acadiana* (0 -> 3), *Balanerpeton woodi* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

12. Bilateral embayment: absent (0); present (1).

From Sea2022 (c.93), FB2020 (c.5)

This distribution of states in this character is related to ch.11, but they are not co-dependent and are therefore retained as separate characters, as is discussed in more detail in ch.11. In cases where there is a reptile-like central bilateral embayment, even if it is small, such as that of *Aerosaurus* (Langston & Reisz, 1981) then this character is scored as 1, regardless of the overall shape of the posterior margin of the skull.

Unambiguous: *Asaphestera intermedia* (0 -> 1), Synapsida (0 -> 1), *Varanops brevirostris* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0), *Euconcordia cunninghami* (0 -> 1), *Paleothyris acadiana* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1).

13. Alary process of premaxilla: absent (0); present (1).

A2001 (c.19), RC2007 (c.1), Cea2016 (c.56), Cea2019 (c.56), Hea2013 (c.26), Pea2017 (c.23). Modified from a division of ML2019 (c.1).

The alary process is a subtriangular bony lappet that originates from the posterodorsal margin of the dorsal ramus of the premaxilla and extends posteriorly, overlapping the nasal. It is a

character associated with temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022) but a similar condition is also present in *Chroniosaurus* (Clack & Klembara, 2009) and indeed nearly all crown tetrapods.

Unambiguous: *Chroniosaurus dongusensis* (0 -> 1), Tetrapoda except *Edops craigi* (0 -> 1).

14. Premaxilla anterior margin: vertical (0); overturned (1).

A2001 (c.48), Hea2013 (c.66), Pea2017 (c.60), RC2007 (c.6), ML2019 (c.4).

The derived condition of this feature refers to the oblique anteroventral surface of the premaxillae, which results in a distinct slope in some taxa and a subterminal mouth opening. It is found in captorhinids (Fox & Bowman, 1966; Reisz et al, 2015), some diadectamorphs (Romer, 1946; Berman et al., 2004), and a number of recumbirostran microsaurs (e.g. Carroll & Gaskill, 1978; Gee et al., 2021) (Huttenlocker et al, 2013).

Unambiguous: *Hyloplesion longicostatum* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Orovenator mayorum* (0 -> 1), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (0 -> 1). ACCTRAN: *Casea*sauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), Diadectamorpha (0 -> 1), *Diadectes abistus* (1 -> 0). DELTRAN: *Casea*sauria (0 -> 1), *Orobates pabsti* (0 -> 1), *Limnoscelis paludis* (0 -> 1).

15. Ratio of maximum width of both premaxillae together to maximum width of skull roof: <0.2 (0); 0.21-0.3 (1); 0.31-0.4 (2); 0.41-0.5 (3); >0.5 (4). (ordered).

RC2007 (c.5), ML2019 (c.3).

The total width of the conjoined premaxillae is measured as the distance between their lateralmost extremities (in dorsal view), the total skull table width is between the lateral extremities of the suspensorium. There is no particularly distinct phylogenetic distribution to this character.

Unambiguous: *Brachydectes newberryi* (2 -> 4), *Asaphestera intermedia* (0 -> 2), *Hapsidopareion lepton* (0 -> 1), *Westlothiana lizziae* (0 -> 4), Embolomeri (2 -> 1), *Dendrerpeton helogenes* (2 -> 4), *Greererpeton burkemorani* (2 -> 3), *Whatcheeria deltae* (2 -> 3). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 0), Adelospondyli (1 -> 4), *Diplocaulus sp.* + *Diploceraspis sp.* (2 -> 0), *Scincosaurus crassus* (2 -> 1), *Phlegethontia linearis* (2 -> 3), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), Edaphosauridae (0 -> 1), Araeoscelidia (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 2), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 2), Temnospondyli (2 -> 3), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (3 -> 2). DELTRAN: Amniota + Diadectamorpha (2 -> 0), *Acherontiscus caledoniae* (1 -> 4),

Diplocaulus sp. + *Diploceraspis sp.* (1 -> 0), *Keraterpeton galvani* (1 -> 2), *Lethiscus stocki* (1 -> 2), *Phlegethontia linearis* (1to3), *Eothyris parkeyi* (0 -> 1), *Edaphosaurus boanerges* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Diadectes abistus* (0 -> 2), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (2 -> 1), *Seymouria sanjuanensis* (2 -> 0), *Balanerpeton woodi* (2 -> 3), *Edops craigi* (2 -> 3).

16. **Number of premaxillary teeth: fewer than 4 (0); 4-6 (1); more than 6 (2). (ordered).**

A2001 (c.56), Cea2016 (c.105), Cea2019 (c.105), Hea2013 (c.74), Pea2017 (c.67).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1), Diplocaulidae (1 -> 2), *Microbrachis pelikani* (1 -> 2), *Asaphestera intermedia* (1 -> 2), *Pantylus cordatus* (1 -> 0), *Westlothiana lizziae* (1 -> 2), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), *Dimetrodon sp.* (1 -> 0), Neoreptilia (1 -> 0), Embolomeri (2 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 2), Adelospondyli (1 -> 2), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 2), Diadectamorpha (1 -> 0), *Diadectes abistus* (0 -> 1). DELTRAN: *Acherontiscus caledoniae* (1 -> 2), *Phlegethontia linearis* (1 -> 2), *Orobates pabsti* (1 -> 0), *Limnoscelis paludis* (1 -> 0), Embolomeri (2 -> 0), *Whatcheeria deltae* (2 -> 1).

17. **Premaxilla, tooth size compared to marginal maxillary teeth: small or subequal to (non-caniniform) maxillary teeth (0); premaxillary teeth larger (1).**

FB2020 (c.20). Modified from Gea1988 (c.114), Rea1992 (c.60), L1993 (c.6), M1994 (c.2), Mea2007 (c.34), Rea2011 (c.36), B2012 (c.18).

Enlarged premaxillary teeth are present in some crownward stem amniotes such as *Hylonomus* (Carroll, 1964) and *Captorhinus* (Fox & Bowman, 1966). They are also present in *Petrolacosaurus* (Reisz, 1977) and many synapsids (e.g. Romer et al., 1940; Bolt & Scott, 1995; Reisz et al., 2009) although they are absent in *Casea* (Olston et al, 1968) and edaphosaurids (Modesto, 1995). Enlarged premaxillary teeth are also known in diadectamorphs (Romer, 1946; Berman et al., 2004) and anthracosaurs (Panchen, 1977; Holmes, 1989), and in the stem tetrapod *Whatcheeria* (Rawson et al., 2021).

Unambiguous: *Procynosuchus delaharpeae* (1 -> 0), *Captorhinus aguti* (0 -> 1), *Hylonomus lyelli* (0 -> 1), Diadectamorpha (0 -> 1), Embolomeri (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Synapsida (0 -> 1), Caseidae (1 -> 0), Edaphosauridae (1 -> 0), *Araeoscelis gracilis* (1 -> 0). DELTRAN: Synapsida (0 -> 1), *Casea broilii* (1 -> 0), *Edaphosaurus boanerges* (1 -> 0), *Petrolacosaurus kansensis* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

18. **Relative proportions of premaxillary teeth: all teeth are approximately equal in size (0); anterior teeth are enlarged, forming conspicuous peak (1).**

Cea2016 (c.104), Cea2019 (c.104), Pea2017 (c.289).

The anteriormost teeth in many synapsids are enlarged relative to the more posterior teeth in the premaxilla, such as *Varanosaurus* (Bolt & Scott, 1995), *Varanops* (Campione & Reisz, 2010), *Casea* (Olson et al., 1968) and *Dimetrodon* (Romer et al., 1940). The condition is also present in araeoscelidians (Reisz, 1977; Langston & Reisz, 1981), as well as *Captorhinus* (Fox & Bowman, 1966), *Limnoscelis* (Romer, 1946) and the microsaurs *Llistrofus* (Gee et al., 2019) and *Pantylus* (Carroll & Gaskill, 1978). The condition is absent in the synapsids *Eothyris* (Reisz et al., 2009) and *Edaphosaurus* (Modesto, 1995) in which the premaxillary teeth are roughly equal in size.

Unambiguous: *Pantylus cordatus* (0 -> 1), *Llistrofus pricei* (0 -> 1), Synapsida (0 -> 1), *Eothyris parkeyi* (1 -> 0), *Limnoscelis paludis* (0 -> 1). ACCTRAN: Edaphosauridae (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (0 -> 1). DELTRAN: *Edaphosaurus boanerges* (1 -> 0), *Captorhinus aguti* (0 -> 1).

19. **Premaxilla-maxilla, occlusal margin between elements: continuous (0), separated by a short diastema (1).**

Modified from J2026(c. 50).

Unambiguous: Sphenacodontia (0 to 1).

20. **Premaxilla, contribution to choana or internal nares contribution to choana or internal nares: absent or weak, premaxilla contributes to the choana via weak point contact (0), present, premaxilla deeply emarginated such as that is forms the anterior, medial, lateral and/or medial margins of choana (1).**

Modified from RCS2020 (c292), J2025

The premaxilla of the earliest tetrapodomorphs such as *Whatcheeria deltae* does not contribute to the internal nares, generally due to an anterolateral swelling of the vomer and a resulting vomerine-maxilla contact (State 0, Rawson et al. 2021). In more crownward stem tetrapods such as *Westlothiana*, the premaxilla makes a short, often point contact with the choana but does not contribute to its concave anterior margin (State 0). Nearly all early-diverging crown tetrapods bear a premaxillary contribution to the choana (State 1).

Unambiguous: Reptiliomorpha (0 → 1), *Anthracosaurus* (0 → 1).

21. **Supraorbital line on premaxilla: absent (0), present (1).**

Modified from Cea2019 (c234).

A supraorbital line is an anterior continuation of the lateral line system that extends onto the lateral surface of the snout, generally the premaxilla and prefrontal (Clack et al. 2019). It is present in only the earliest-diverging stem tetrapods (e.g., *Greererpeton*, Smithson 1982) as well as adelospondylid "lepospondyls" (Andrew and Carroll 1992). There are no supraorbital lines in *Westlothiana*, embolomeres, or crown tetrapods (Panchen and Smithson 1987).

Unambiguous: (Tetrapodomorpha more derived than adelospondylids 0 → 1).

22. Internarial (interpremaxillary) fontanelle or fenestra: absent (0), present (1).

Modified from RCS2020 (c92) and Cea2019 (c234).

The internarial fontanelle (sometimes referred to as a 'dorsal fontanelle') is a fenestra between the two premaxillae that can be visible in anterior view. The internarial fontanelle is present in stem tetrapod groups including aistopods (Pardo et al. 2017), *Acanthostega* (Porro et al. 2015), and *Westlothiana* (this study).

Unambiguous: *Westlothiana* + *Utaherpeton* (0 → 1). DELTRAN: *Westlothiana* + *Utaherpeton* + Aistopoda (0 → 1). ACCTRAN: Total-group Amniota (0 → 1).

23. Distinctly ossified septomaxilla: absent (0); present (1).

A2001 (c.20), Rea2003 (c.10), Hea2013 (c.28), Pea2017 (c.24).

Unambiguous: *Discosauriscus austriacus* (1 -> 0). ACCTRAN: Embolomeri + *Chroniosaurus dongusensis* (1 -> 0). DELTRAN: *Anthracosaurus russelli* (1 -> 0).

24. Position of highest point of maxilla dorsal margin along length of maxilla: in anterior third (0); at midlength (1); in posterior half (2).

Cea2016 (c.28), Cea2019 (c.28).

Unambiguous: *Asaphestera intermedia* (1 -> 0), *Huskerpeton englehorni* (1 -> 2), *Pantylus cordatus* (1 -> 0), *Llistrofus pricei* (1 -> 0), *Westlothiana lizziae* (1 -> 0), *Varanops brevirostris* (1 -> 0), Caseasauria (1 -> 0), Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1), *Hylonomus lyelli* (1 -> 0), *Archeria crassidisca* (1 -> 2), *Balanerpeton* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Amniota (1 -> 0), .Synapsida (0 -> 1), *Araeoscelis gracilis* (0 -> 1), Seymouriamorpha (1 -> 0), Embolomeri (0 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus*

janenschi (0 -> 1), *Varanosaurus acutirostris* (1 -> 0), *Petrolacosaurus* (1 -> 0), Reptilia (1 -> 0), *Gephyrostegus bohemicus* (0 -> 1), *Anthracosaurus* (0 -> 1).

25. **Maxilla, preorbital ascending process, maximum dorsoventral height in respect to the height of the maxilla at the anterior orbital margin: less than 1.5 times the height (0); between 1.5 and twice the height (1); greater than twice the height (2). (ordered).**

FB2020 (c.24). Modified from L1993 (c.29), Bea1995 (c.34), RD2003 (c.5), B2012 (c.25), Sea2018 (c.21).

This character is taken from Ford & Benson (2020). An enlarged, relatively deep anterior region of the maxilla is found the stem tetrapod *Greererpeton* (Smithson et al, 1981), the microsaur *Hyloplesion* (Carroll & Gaskill, 1978) and a variety of crown amniote taxa (Langston & Reisz, 1981; Bolt & Scott, 1995; Ford & Benson, 2019), as well as in *Westlothiana*. A further enlarged, particularly deep maxilla anterior region (state 2) is found in sphenacodontids (Romer et al., 1940) and the microsaur *Pantylus* (Carroll & Gaskill, 1978). It is included to help differentiate between different crown amniote groups, although this feature may be widespread among unsampled stem tetrapods.

Unambiguous: *Hyloplesion longicostatum* (0 -> 1), *Pantylus cordatus* (0 -> 2), *Westlothiana lizziae* (0 -> 1), Synapsida (0 -> 1), *Varanops brevirostris* (1 -> 2), Caseasauria (1 -> 0), Sphenacodontidae (1 -> 2), *Youngina capensis* (0 -> 2), *Orovenator mayorum* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Captorhinidae (0 -> 1). DELTRAN: *Captorhinus aguti* (0 -> 1).

26. **Maxilla length relative to palatine: shorter than palatine (0); longer than palatine (1).**

A2001 (c.52), Hea2013 (c.70), Pea2017 (c.63).

A maxilla that has become stout and is shorter than the palatine is present in nectrideans (Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), and is also seen in the microsaur *Hyloplesion* (Carroll & Gaskill, 1978).

Unambiguous: Nectridea (1 -> 0), *Hyloplesion longicostatum* (1 -> 0).

27. **Posterior extent of maxilla relative to posterior margin of orbit: maxilla does not extend posterior to orbit (0); maxilla extends posterior to orbit (1).**

Cea2016 (c.29), ML2019 (c.21), Cea2019 (c.29), Pea2017 (c.267). Modified from Rea2003 (c.28, c.33), RC2007 (c.27, c.32).

State 0 of this character, in which the posterior end of maxilla is restricted anteriorly, is observed in most former "lepospondyls", including microsaurs (Carroll & Gaskill, 1978) and nectrideans (Beerbower, 1963; Milner & Ruta, 2009), but in aïstopods (Anderson, 2002; Pardo et al, 2017) the plesiomorphic condition is observed, in which the maxilla terminates posterior to the posterior margin of the orbit. The derived condition, state 0, also occurs in several stem and basal crown amniotes including captorhinids (Fox & Bowman, 1966; Reisz et al, 2016), araeoscelidians (Reisz, 1977; Reisz et al, 1984), some synapsids (e.g. Laurin, 1993; Bolt & Scott, 1995), former "parareptiles" (Gow, 1972; Reisz et al, 2007) and *Youngina* (Gow, 1974). This occurs in some stem tetrapods such as *Archeria* (Holmes, 1989) and the reptiliomorph *Solenodonsaurus* (Danto et al, 2012).

Unambiguous: Nectridea (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), *Archeria crassidisca* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Euryodus sp.* (0 -> 1), Seymouriamorpha (1 -> 0).

28. Maxilla, lateral 'supracanine' buttress: absent or slight swelling (0); distinct lateral swelling or dorsally oriented ridge on the maxilla, dorsal to the caniniform dentition (1).

FB2020 (c.36), Rea1998 (c.10), RD2003 (c.10), Mea2006 (c.11), Rea2009 (c.13), B2012 (c.36), Bea2016 (c.25), Sea2018 (c.24).

A lateral swelling of the maxilla, above the caniniform teeth, is associated with several synapsids (e.g. Laurin, 1993; Modesto, 1995; Mann & Paterson, 2020).

Unambiguous: *Varanops brevirostris* (0 -> 1), *Eothyris parkeyi* (0 -> 1), Sphenacodontidae (0 -> 1), *Varanosaurus acutirostris* (0 -> 1).

29. Maxilla, 'supracanine' buttress on medial surface: absent, alveolar shelf has uniform or gradually tapering dorsoventral height (0); present, subtriangular dorsal thickening of anterior alveolar shelf (1).

FB2020 (c.37). Modified from Rea1992 (c.27), L1993 (c.28 c.70), Bea1995 (c.33), Fea2011 (c.21,c.56), B2012 (c.37), Sea2018 (c.25).

A medial swelling of the maxilla, like the previous character, is seen in some synapsids such as *Archaeovenator* (Reisz & Dilkes, 2003; Bolt & Scott, 1995; Mann & Paterson, 2020), but is also noted in *Youngina capensis* (Gow, 1974) and *Orovenator* (Ford & Benson, 2019).

Unambiguous: *Echinerpeton intermedium* (0 -> 1), Sphenacodontia (0 -> 1), *Varanosaurus acutirostris* (0 -> 1). ACCTRAN: Reptilia (0 -> 1), Neoreptilia (1 -> 0). DELTRAN: *Archaeovenator* (0 -> 1), *Orovenator* (0 -> 1).

30. **Maxilla, ventral surface in lateral view: straight or weakly convex (0); pronounced convexity (1).**

FB2020 (c.44). Modified from Gea1988 (c.30), Rea1992 (c.25), Bea1995 (c.31), RD2003 (c.52), Mea2008 (c.12), B2012 (c.27).

A pronounced convexity in the ventral surface of the maxilla is primarily associated with the skull shape of sphenacodontids (Romer et al., 1940; Laurin, 1993), but is also found in *Acherontiscus* (Clack et al., 2019), *Lethiscus* (Pardo et al., 2017) and *Varanosaurus* (Bolt & Scott, 1995).

Unambiguous: *Acherontiscus caledoniae* (0 -> 1), *Lethiscus stocki* (0 -> 1), Sphenacodontia (0 -> 1), *Varanosaurus acutirostris* (0 -> 1).

31. **Number of maxillary teeth: fewer than 13 (0); 14-29 (1); 30-40 (2); greater than 40 (3) (ordered).**

A2001 (c.57), RC2007 (c.235), Cea2016 (c.96), ML2019 (c.189), Cea2019 (c.96), Hea2013 (c.75), Pea2017 (c.68).

The states for this character are taken from Marjanovic & Laurin (2019 c189). The states used in that analysis were chosen to better represent phylogenetic distributions, according to the authors of that study, as opposed to previous analyses where state distribution arbitrarily followed multiples of 10, a decision we concur with here. Most stem and crown amniotes crownwards of former "lepospondyls" range from approximately 15 to 30 teeth (e.g. Romer et al., 1940; Gow, 1972; 1974; Reisz, 1977; Modesto, 1995; Reisz et al., 2009), with just a few exceptions including protorothyridids, which possess around 35 teeth (Carroll, 1964; 1969), *Varanosaurus* which has around 56 teeth (Bolt & Scott, 1995), and the parareptile *Belebey* which possesses just 10 teeth (Reisz et al., 2007). Temnospondyls mostly have in excess of 30 teeth (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010). Many microsaurs are characterised by a particularly low tooth number, often lower than 14, such as *Pantylus*, *Cardiocephalus* (Carroll & Gaskill, 1978) and *Euryodus* (Gee et al., 2021).

Unambiguous: *Adelogyrinus simorhynchus* (1 -> 2), *Diplocaulus sp. + Diploceraspis sp.* (0 -> 1), *Oestocephalus sp.* (1 -> 2), *Westlothiana lizziae* (1 -> 2), *Varanosaurus acutirostris* (1 -> 3), *Belebey vegrandis* (1 -> 0), *Opisthodontosaurus carrolli* (1 -> 0), *Diadectes abistus + Orobates pabsti* (1 -> 0), *Gephyrostegus bohemicus* (1 -> 2), *Silvanerpeton miripedes* (1 -> 2), *Archeria crassidisca* (1 -> 3), *Chroniosaurus dongusensis* (1 -> 2), *Caerorachis bairdi* (1to3), *Balanerpeton woodi* (1 -> 2), *Doleserpeton annectens + Gerobatrachus hottoni* (1 -> 3), *Baphetes sp.* (1 -> 2), *Greererpeton burkemorani* (1to3). ACCTRAN: *Cardiocephalus sp.*

+ *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Huskerpeton englehorni* (0 -> 1), Caseidae (1 -> 0). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0), *Casea broilii* (1 -> 0).

32. Shape of marginal teeth: blunt and peg-like (0); sharp, conical and straight (1); sharp and recurved (2); chisel tipped (3).

Modified from A2001 (c.55, c.58), Rea2003 (c.222, c.224), RC2007 (c.232, c.234), ML2019 (c.186, c.187, c.188), Hea2013 (c.73, c.76), Pea2017 (c.66, c.69).

The states in this character are combined from multiple different characters in previous analyses, in order to incorporate most possible tooth shapes into a single character. Many microsaurs bear blunt, peg-like teeth with a rounded tip (Carroll & Gaskill, 1978). Sharp and recurved teeth are common across amniotes (Bolt & Scott, 1995; Modesto, 1995; Campione & Reisz, 2010; Brocklehurst et al., 2016). This character should ultimately be broken up back into its constituent characters.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 2), *Adelogyrinus simorhynchus* (0 -> 3), Aïstopoda (0 -> 1), *Scincosaurus crassus* (1 -> 3), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), Caseasauria + *Echinerpeton intermedium* (2 -> 1), Araeoscelidia (2 -> 1), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (2 -> 0), *Ariekanerpeton sigalovi* (1 -> 2), *Archeria crassidisca* (1 -> 3), *Chroniosaurus dongusensis* (1 -> 2). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (2 -> 1), Sphenacodontidae + *Pantelosaurus saxonicus* (2 -> 1), *Diadectes abistus* + *Orobates pabsti* (2 -> 3). DELTRAN: *Pantelosaurus saxonicus* (2 -> 1), *Diadectes abistus* (2 -> 3), *Whatcheeria deltae* (1 -> 2).

33. Marginal tooth morphology: single cusps (0); multiple cusps (1).

A2001 (c.60), Rea2003 (c.219), Hea2013 (c.78), Pea2017 (c.71). Modified from LR1997 (c.97), Lea1998 (c.93), ML2019 (c.183, c.190).

In stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) the teeth possess a single cusp, a condition that is almost ubiquitous across the crown tetrapods included in this analysis. A small number of taxa including some diadectamorphs (Berman et al., 1998; 2004), synapsids (Olson et al., 1968; Kemp, 1979), the parareptile *Belebey* (Reisz et al., 2007) and the temnospondyl *Doleserpeton* (Sigurdsen & Bolt, 2010) possess multiple cusps.

Unambiguous: *Casea broilii* (0 -> 1), *Procynosuchus delaharpeae* (0 -> 1), *Belebey vegrandis* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

34. Orientation of multiple tooth cusps: labiolingual (0); anteroposterior (1).

A2001 (c.61), Rea2003 (c.220), RC2007 (c.229), Hea2013 (c.79), Pea2017 (c.72).

In *Casea* the multiple tooth cusps are arranged anteroposteriorly (Olson et al, 1968).

ACCTRAN: Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1). DELTRAN: *Casea broilii* (0 -> 1).

35. Dimple on marginal teeth: absent (0); present (1).

Rea2003 (c.223), RC2007 (c.233), Cea2019 (c.235).

A small dimple on the marginal teeth is present in *Adelogyrinus* (Andrews & Carroll, 1991).

Unambiguous: *Adelogyrinus simorhynchus* (0 -> 1).

36. Marginal teeth pedicelly: teeth are non-pedicellate (0); teeth are pedicellate (1).

Hea2013 (c.134), LR1997 (c.98), Lea1998 (c.94), Rea2003 (c.218), RC2007 (c.228), ML2019 (c.182), Pea2017 (c.80).

Tooth pedicelly is a feature of dissorophoid temnospondyls (Sigurdsen & Bolt, 2010) and *Gerobatrachus* (Anderson et al., 2008). In these taxa, the teeth bear a base, or pedicel, upon which the apical portion of the tooth crown sits.

Unambiguous: *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1).

37. Labyrinthine infolding of teeth: absent (0); present (1).

LR1997 (c.100), Lea1998 (c.96), A2001 (c.63), Hea2013 (c.81), Pea2017 (c.74).

Labyrinthine infolding of the teeth is present in stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021), as well as basally diverging temnospondyls (Milner & Sequeira, 1993; Arbez et al., 2021). Labyrinthine infolding of the teeth is absent in small-bodied tetrapods *Caerorachis* (although it is present in the palatal fangs, Ruta et al., 2001) and most total-group amniotes, although plicidentine grooves are present at the base of the tooth in this group until the Triassic.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Limnoscelis paludis* (0 -> 1). ACCTRAN: *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Doleserpeton annectens* (1 -> 0).

38. Marginal tooth size along row, excluding caniniform teeth: consistent along row (0); decrease in size posteriorly along row (1).

A2001 (c.54), Hea2013 (c.72), Pea2017 (c.65) Modified from Hea2013 (c.77), A2001 (c.59).

In stem tetrapods (Beaumont, 1977; Smithson, 1981; Rawson et al., 2021) the teeth are approximately uniform in size along the anteroposterior length of the tooth row, a condition also observed in anthracosaurs (Panchen, 1977; Holmes, 1989) such as *Silvanerpeton* (Ruta & Clack, 2006). In most stem and crown amniote taxa more derived than microsaurs, the marginal dentition decreases in size steadily towards the posterior end of the toothrow, including protorothyridids (Carroll, 1964; 1969), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016), *Petrolacosaurus* (Reisz, 1977; many synapsids (e.g. Langston & Reisz, 1981; Bolt & Scott, 1995; Reisz et al., 2009), “former "parareptiles"” (Gow, 1972; Modesto et al., 2015) and *Youngina* (Gow, 1974). This condition is also present in some former "lepospondyls", namely the aïstopod *Phlegethontia* (Anderson, 2002) and some microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2019; 2021) but not in other aïstopods (Carroll, 1998; Pardo et al., 2017), diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009) and other microsaurs (Carroll & Gaskill, 1978; Carroll et al., 1991).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Phlegethontia linearis* (0 -> 1), *Cardiocephalus sp.* (1 -> 0), *Micraroter erythrogeois* (1 -> 0), *Hapsidopareion* (1 -> 0), *Varanops brevirostris* (1 -> 0), *Echinerpeton intermedium* (1 -> 0), *Araeoscelis gracilis* (1 -> 0), *Edops craigi* (0 -> 1).

39. Caniniform teeth, identified by forming conspicuous peak in the middle or the marginal tooth row: absent, tooth size is consistent along row or change size gradationally along whole row (0); present (1).

Hea2013 (c.77), A2001 (c.59), Cea2016 (c.97), Cea2019 (c.97).

Distinct caniniform teeth, clearly larger than the adjacent marginal teeth, are present and are a prominent feature of captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), protorothyridids (Carroll, 1964; 1969), araeoscelidians (Reisz, 1977; Reisz et al., 1984) and most synapsids (e.g. Laurin, 1993; Reisz et al., 2009; Campione & Reisz, 2010). They are also present in a small number of microsaurs (Carroll & Gaskill, 1978; Gee et al., 2021) and diadectamorphs (Romer, 1946; Berman et al., 1998; 2004).

Unambiguous: *Hyloplesion longicostatum* (0 -> 1), *Euryodus sp.* (0 -> 1), *Pantylus cordatus* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Edaphosauridae (1 -> 0), Reptilia (1 -> 0), *Anthracosaurus russelli* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), *Eothyris parkeyi* (0 -> 1). DELTRAN: *Casea* broili (1 -> 0), *Echinerpeton intermedium* (1 -> 0), *Whatcheeria deltae* (0 -> 1).

40. Position of external naris ventral rim relative to naris height: ventral rim closer to jaw margin than height of naris (0); ventral rim further from jaw margin than height of naris (1).

LR1997 (c.9), L1998 (c.9), Cea2016 (c.160), Cea2019 (c.160).

In nectrideans, the flattened skull results in a relatively dorsal position of the external naris so that it is further from the ventral rim of the skull than the height of the naris (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018). The naris of *Limnoscelis* is dorsoventrally shallow, and is positioned relatively dorsally on the deep snout (Romer, 1946) so this taxon also scores state 1 for this character, as do *Anthracosaurus* (Panchen, 1977) and *Dendrerpeton* (Arbez et al, 2022).

Unambiguous: Nectridea (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Anthracosaurus russelli* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1).

41. External naris exposed in dorsal view: not exposed (0); exposed (1).

A2001 (c.22), Hea2013 (c.30), Pea2017 (c.26).

The external naris is exposed in dorsal view in most ingroup taxa. However, in some taxa, the snout can be relatively narrow and deep, resulting in a laterally facing naris, such as *Oestocephalus* (Carroll, 1998), and *Archeria* (Holmes, 1989) and diadectamorphs (Berman et al, 1998; Berman et al, 2004) in which the nasals are transversely broad and take up the entire dorsal roof of the snout. The recumbent snout in several microsaurs (Carroll & Gaskill, 1978; Gee et al, 2021) restricts the naris to a ventrolateral orientation.

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), *Oestocephalus sp.* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Westlothiana lizziae* (1 -> 0), Diadectamorpha (1 -> 0), *Archeria crassidisca* (1 -> 0), *Pederpes finneyae* (0 -> 1). ACCTRAN: Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0). DELTRAN: *Eothyris parkeyi* (1 -> 0).

42. External naris, posterodorsal expansion: absent (0); present (1).

FB2020 (c.45). Modified from RD2003 (c.43), Mea2006 (c.42), Rea2009 (c.9), Rea2010 (c.21), B2012 (c.4), Sea2018 (c.5).

A distinct expansion of the external naris is present in the varanopids as well as *Orovenator* (Ford & Benson, 2020).

Unambiguous: *Varanops brevirostris* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: Reptilia (0 -> 1), Neoreptilia (1 -> 0). DELTRAN: *Archaeovenator hamiltonensis* (0 -> 1), *Orovenator mayorum* (0 -> 1).

43. Separately ossified nasals: entirely absent (0); present (1).

A2001 (c.18), Hea2013 (c.24), Pea2017 (c.21). Modified from a division of Rea2003 (c.12), RC2007 (c.10), ML2019 (c.8).

The nasals are lost in derived diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963). In the taxa studied, these are also the only taxa in which the premaxilla contacts the frontals, and as such a character for the latter condition is not included.

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0).

44. Paired nasals present: no, nasals fused into single median element (0); yes (1); nasals entirely absent (inapplicable).

Modified from division of Rea2003 (c.12), RC2007 (c.10), ML2019 (c.8).

This character does not vary amongst taxa included in this analysis, but the character is retained to allow future expansion of the data matrix to panderichthyids or even more stemward stem tetrapods, in which paired nasals are absent (Ruta et al., 2003).

45. Separately ossified lacrimal: absent (0); present (1).

A2001 (c.9), Rea2003 (c.23), RC2007 (c.22), ML2019 (c.18), Hea2013 (c.13), Pea2017 (c.10).

A separately ossified lacrimal is absent in some former "lepospondyls", including *Diploceraspis* (Beerbower, 1963) and *Phlegethontia* (NMW.1899.IX.13b; Anderson, 2002) from the current dataset.

Unambiguous: *Diploceraspis sp.* (1 -> 0), *Phlegethontia* (1 -> 0).

46. Lacrimal ventral orbital process: absent (0); present (1).

A2001 (c.9), Rea2003 (c.23), RC2007 (c.22), ML2019 (c.18), Hea2013 (c.13), Pea2017 (c.10)

This, and the following character, describe a process of the lacrimal that curves round the anteroventral orbit margin and is clearly and distinctly separate from the main body of the bone, as seen clearly in *Petrolacosaurus* (Reisz, 1977) and *Llistrofus* (Gee et al, 2019), for example. A ventral process is present in almost all microsaurs (Carroll & Gaskill, 1978) and other former "lepospondyls" (Anderson, 2002; Pardo et al, 2017). It also present in many amniote taxa, including crown ward stem amniotes such as captorhinids and protorothyridids (Fox & Bowman, 1966; Carroll, 1969), edaphosaurids (Reisz & Berman, 1986; Modesto,

1995), varanopids (Langston & Reisz, 1981; Campione & Reisz, 2010) and some basal former "parareptiles" (Reisz et al, 2007; Modesto et al, 2015) but is absent in most other synapsids (e.g. Bolt & Scott, 1995; Reisz et al, 2009).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (0 -> 1), Adelospondyli (1 -> 0), Nectridea (1 -> 0), Temnospondyli except *Edops craigi* (0 -> 1). ACCTRAN: Synapsida (1 -> 0), Varanopidae (0 -> 1), Edaphosauridae (0 -> 1), Neoreptilia (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1), Diadectamorpha (1 -> 0), *Orobates pabsti* (0 -> 1). DELTRAN: Caseasauria (1 -> 0), Sphenacodontia (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), *Youngina capensis* (1 -> 0), *Milleropsis pricei* (1 -> 0), *Diadectes abistus* (1 -> 0), *Limnoscelis paludis* (1 -> 0).

47. Lacrimal dorsal orbital process: absent (0); present (1).

Modified from A2001 (c.12), Hea2013 (c.16), Pea2017 (c.14).

Unlike the previous character, a dorsal process of the lacrimal is less widespread. A dorsal process is primarily associated with microsaurs, where it is present in all taxa apart from *Hyloplesion* and *Hapsidopareion* (Carroll & Gaskill, 1978). It is also noted in a small selection of amniote taxa.

Unambiguous: *Hapsidopareion lepton* (1 -> 0). ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 1), *Hylonomus lyelli* (1 -> 0). DELTRAN: Captorhinidae (0 -> 1), *Paleothyris acadiana* (0 -> 1).

48. Distinct dorsal process on maxilla dorsal margin forming a distinct dorsal ‘step’: absent, dorsal margin of maxilla is smooth (0); present (1).

ML2019 (c.25), Rea2003 (c.32), RC2007 (c.31).

This character describes a condition in which a raised section of the dorsal margin of the maxilla is present, defined by sharp angles of close to 90 degrees from the rest of the dorsal margin. It is most clearly seen and recognised in *Pantylus* (FM UC 1075; Carroll & Gaskill, 1978), which is a good example of this state, but is also observed in other taxa including *Eothyris* (Reisz et al, 2009) and *Casea* (Olson et al, 1968).

Unambiguous: *Utaherpeton franklini* (0 -> 1), *Pantylus cordatus* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), *Dimetrodon sp.* (0 -> 1). ACCTRAN: *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1). DELTRAN: *Doleserpeton annectens* (0 -> 1).

49. Jugal - lacrimal contact: absent, maxilla makes contribution to orbit margin (0); present, excluding maxilla from orbit margin (1).

Novel

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0), *Micraroter erythrogeois* (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0). DELTRAN: Adelospondyli (1 -> 0), Aïstopoda (1 -> 0), *Euryodus sp.* (1 -> 0).

50. Prefrontal maximum length along long axis relative to maximum width perpendicular to long axis: less than three times longer than wide (0); at least three times longer than wide (1).

Rea2003 (c.16), RC2007 (c.15), Cea2016 (c.53), ML2019 (c.13), Cea2019 (c.53), Pea2017 (c.270).

The length is calculated, in dorsal or lateral aspect as appropriate, as the distance between the anterior and posterior extremities of the bone. Elongation of the prefrontals occurs in a disparate selection of taxa, such as *Westlothiana*, *Greererpeton* (Smithson, 1981), sphenacodontids (e.g. Romer et al, 1940), *Petrolacosaurus* (Reisz, 1977), and many microsaurs (Carroll & Gaskill, 1978).

Unambiguous: Nectridea (1 -> 0), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), *Tuditanus punctulatus* (1 -> 0), *Pantylus cordatus* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), Sphenacodontia (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Euconcordia cunninghami* (0 -> 1), *Paleothyris acadiana* (0 -> 1), *Diadectes abistus* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Adelospondyli (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), Seymouriamorpha (1 -> 0). DELTRAN: *Adelogyrinus simorhynchus* (1 -> 0), *Solenodonsaurus janenschi* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1).

51. Prefrontal - postfrontal contact: absent, frontal makes contribution to orbit margin (0); present, excluding frontal from orbit margin (1).

When the postfrontal and prefrontal contact, they obscure the frontal from making a contribution to the orbit. The frontal contribution to the orbit margin is a character of crown amniotes (e.g. Gow, 1974; Bolt & Scott, 1995; Brocklehurst et al., 2016) and their closest relatives, captorhinids (Fox & Bowman, 1966; Reisz et al., 2016), *Hylonomus* (Carroll, 1964) and *Paleothyris* (Carroll, 1969). There are, however, other cases where the frontal contacts the orbit in a number of former "lepospondyls" (Beerbower, 1963; Anderson, 2002; Pardo et al., 2016; 2017), *Chroniosaurus* (Clack & Klembara, 2009) and dissorophoid temnospondyls (Anderson et al., 2008; Sigurdsen & Bolt, 2010).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), *Llistrofus pricei* (1 -> 0), *Hylonomus lyelli*

+ *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Procynosuchus delaharpeae* (0 -> 1), *Opisthodontosaurus carrolli* (0 -> 1), *Chroniosaurus dongusensis* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0).

52. Prefrontal, ventral process forms expanded antorbital buttress: absent (0), present (1).

Modified from J2026 (c. 136).

Unambigous: Recumbirostra (0 to 1). ACCTRAN: Total-group Reptilia (0 to 1).

53. Prefrontal into naris: absent (0), present (1).

Modified from RCS2020 (c18) and Cea2019 (c54).

The elongate prefrontal contributes to the external nares in stem tetrapods such *Greererpeton* (Smithson, 1982), adelospondylids (Andrew and Carroll 1992), aistopods (Pardo et al. 2017), *Westlothiana* (this study), and rarely in total-group amniotes including some recumbirostran microsaurs (e.g., *Hapsidopareion*, Jenkins et al. 2025a).

Unambiguous: *Greererpeton* (0 → 1), *Westlothiana* + *Utaherpeton* + Aistopoda (0 → 1), *Keraterpeton* (0 → 1), Recumbirostra excluding *Pantylus* (0 → 1).

54. Prefrontal, contact with premaxilla: absent (0), present (1).

This study.

The prefrontal contacts the premaxilla dorsal to the narial margin only in *Greererpeton*, *Westlothiana,* and *Utaherpeton* within this sampling (Carroll et al. 1991).

Unambiguous: *Greererpeton* (0 → 1), *Westlothiana* + *Utaherpeton* (0 → 1).

55. Prefrontal, lateral surface: convex (0), concave (1).

Modified from J2026 c. 129).

Unambiguous: Sphenacondontia (0 to 1).

56. Flange from skull roof articulating with sphenethmoid or orbitosphenoid: absent (0), present (1).

Modified from Pea2017 (c195).

When ossified, the w or u-shaped orbitosphenoid of early tetrapods and the y-shaped sphenethmoid of crownward total-group amniotes may abut the ventral surface of the frontal, generally at the level of the crista cranii. However, in recumbirostran microsaurs including molgophids, the frontal (and sometimes prefrontal) bears a flange directly bracing the sphenethmoid (Pardo et al. 2017).

Unambiguous: Recumbirostra more derived than *Pantylus* $(0 \rightarrow 1)$.

57. Separately ossified frontals: absent (0); present (1).

Cea2019 (c.224), Pea2017 (c.266).

This character does not vary within the taxon sample in this analysis. However, it is retained to allow for future expansion of the taxon sample towards deeper stem taxa, such as the addition of osteolepiforms, which may lack frontals (Zhang & Yu, 1997).

58. Paired frontals: absent, frontals fused into single median element (0); present, frontals are separately-ossified paired elements with a midline contact (1); no ossified frontals (inapplicable).

A2001 (c.16), Rea (c.34), RC2007 (c.33), ML2019 (c.26), Hea2013 (c.21), Pea2017 (c.18).

Fusion of the frontals into a single, median element occurs in derived diplocaulid nectrideans (MCZ3009; Douthitt, 1917; Beerbower, 1963), and also in the aïstopod *Phlegethontia* (MCZ 2038; Anderson, 2002).

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0), *Phlegethontia linearis* (1 -> 0).

59. Frontal anterior margin wedged between nasals: absent (0), present (1).

Rea2003 (c.38), RC2007 (c.37), Cea2017 (c.11), Cea2019 (c.11), ML2019 (c.30)

This character describes a condition in which the anterior margin of the frontals extends distinctly between the nasals, forming a roughly triangular anterior process, with the nasals and frontals overlapping considerably along the anterior-posterior axis. State 1 is present in a widespread selection of disparate taxa.

Unambiguous: Adelospondyli (0 -> 1), *Phlegethontia linearis* (0 -> 1), *Varanosaurus acutirostris* (0 -> 1), Neoreptilia (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Discosauriscus austriacus* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1), Embolomeri (0 -> 1), *Greererpeton burkemorani* (0 -> 1), *Whatcheeria deltae* (0 -> 1)

60. Frontal length:nasal length ratio: nasals longer than frontals (0), frontals approximately equal in length to, or longer than, nasals (1).

Cea2016 (c.12), Cea2019 (c.12).

Most taxa possess frontals that are at least as long as the nasals, and usually longer. However, some clades show an elongation of the nasals, notably sphenacodontids (Romer et al, 1940), “anthracosaurs” (Panchen, 1977; Holmes, 1989), some former "parareptiles" (Reisz et al, 2007) and *Youngina* (Gow, 1974).

Unambiguous: *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0), Embolomeri (1 -> 0), *Baphetes sp.* (1 -> 0). ACCTRAN: Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 0). DELTRAN: Sphenacodontidae (1 -> 0)

61. Anteroposterior length of frontals in relation to anteroposterior length of parietals: parietals shorter (0); frontals and parietals approximately equal in length (1); parietals longer (2). (ordered).

Rea2003 (c.35), RC2007 (c.34), Cea2016 (c.10), Cea2019 (c.10), ML2019 (c.27)

The left and right elements of both of these paired bones tend to be similar in length, but where there was a small disparity the larger was chosen to take measurements. The distribution of character states does not appear to be congruent either between or within groups. Microsaurs, in particular, show a large variety of states. For example, the parietals are shorter (state 0) in *Tuditanus* and *Hapsidopareion* (Carroll & Gaskill, 1978), approximately equivalent (state 1) in *Pantylus* (Carroll & Gaskill, 1978) and *Huskerpeton* (Huttenlocker et al., 2013), and the parietals are longer (state 2) in *Cardiocephalus* (Carroll & Gaskill, 1978) and *Euryodus* (Gee et al., 2021).

Unambiguous: *Utaherpeton franklini* (2 -> 1), *Brachydectes newberryi* (2 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 2), *Llistrofus pricei* (0 -> 2), *Varanosaurus acutirostris* (0 -> 1), *Hylonomus lyelli* (0 -> 1), *Ariekanerpeton sigalovi* (0 -> 1), *Dendrerpeton helogenes* (0 -> 2). ACCTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (2 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 2). DELTRAN: *Lethiscus stocki* (2 -> 1), *Eothyris parkeyi* (0 -> 2)

62. Frontal, contribution to orbital margin: narrow (0); broad, >1/4 of maximum orbital length (1); inapplicable, frontal does not contribute to orbital margin (inapplicable).

FB2020 (c63). Modified from RRea1992 (c.11), Rea1998 (c.13), RD2003 (c.13), Mea2006 (c.18), Rea2009 (c.19), Rea2010 (c.26), B2012 (c.60), Sea2018 (c.40).

The frontal makes a particularly small contribution to the orbit, in taxa where it still makes a contribution, in captorhinids (Fox & Bowman, 1966; Reisz et al., 2016) and the caseasaurs *Eothyris* (Reisz et al., 2009) and *Casea* (Olson et al., 1968).

Unambiguous: Captorhinidae (1 -> 0). ACCTRAN: *Recumbirostra*(1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), Embolomeri + *Chroniosaurus dongusensis* (1 -> 0). DELTRAN: *Llistrofus pricei* (1 -> 0), Caseasauria (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0).

63. Ossifications within the orbit: absent (0); present (1).

Hea2013 (c.49). Modified from a division of Pea2017 (c.45).

Ossifications within the orbit, whether that is a single ossification, as in *Huskerpeton* (Huttenlocker et al, 2013) or multiple sclerotic plates as in the crown amniote *Orovenator* (Ford & Benson, 2019), occur in a widespread selection of taxa, and are indeed present in nearly all taxa in this sampling. As well as these taxa, they are present in a range of other taxa from former "lepospondyls" such as *Hapsidopareion* and *Microbrachis* (Carroll & Gaskill, 1978), other stem amniotes such as *Gephyrostegus* (Klembara et al., 2014) and even stem tetrapods such as *Baphetes* (Beaumont, 1977), unsurprising given their presence in many vertebrates.

Unambiguous: *Scincosaurus crassus* (0 -> 1), Neoreptilia (0 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0), *Orobates pabsti* (0 -> 1), *Ariekanerpeton sigalovi* (0 -> 1), *Baphetes sp.* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Huskerpeton englehorni* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), Seymouriamorpha (1 -> 0), Temnospondyli except *Edops craigi* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0), *Solenodonsaurus janenschi* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1), *Balanerpeton woodi* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1).

64. Ossifications within orbit: single large plate (0); mosaic of bony plates (1), no orbital ossifications (inapplicable).

Modified from a division of Pea2017 (c.45).

Unambiguous: *Gephyrostegus bohemicus* (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0). DELTRAN: *Huskerpeton englehorni* (1 -> 0).

65. Raised orbital rim: absent (0); present (1).

A2001 (c.30), Hea2013 (c.44), Pea2017 (c.40).

A raised orbital rim describes a condition in which at least some of the circumorbital bones are transversely thickened immediately adjacent to the orbit, and is very clearly evident in *Gephyrostegus* (Klembara et al., 2014). A raised rim is present in a variety of taxa, but primarily within microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2021) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005).

Unambiguous: *Hyloplesion longicostatum* (0 -> 1), Sphenacodontia (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0), *Varanosaurus acutirostris* (0 -> 1), *Milleropsis pricei* (0 -> 1), Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: *Recumbirostra*(0 -> 1), *Hapsidopareion lepton* (1 -> 0). DELTRAN: *Asaphestera intermedia* (0 -> 1), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni + Micraroter erythrogeois* (0 -> 1).

66. Ratio of length and depth of orbit: orbit deeper than long (0); orbit height and depth subequal (1), orbit longer than deep (2).g

RC2007 (c.109), ML2019 (c.89). Modified from a division of Cea2016 (c.163), Cea2019 (c.163), LR1997 (c.5), Lea1998 (c.5).

The depth of the orbit is greater than its maximum anteroposterior length in the outgroup, in *Whatcheeria* (Rawson et al, 2021) and *Pederpes* (Clack & Finney, 2005). A small number of ingroup taxa show a reversal to this condition, such as *Discosauriscus* (Klembara, 1997), *Chroniosaurus* (Clack & Klembara, 2009) and edaphosaurids (Modesto, 1995).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Edaphosauridae (1 -> 0), *Discosauriscus austriacus* (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0).

67. Orbit maximum anteroposterior length relative to anteroposterior distance between posterior orbit margin and posterior skull margin: orbit length is shorter than this distance (0); orbit length is at least as long as this distance (1).

RC2007 (c.110), ML2019 (c.90).

The distribution of different states of this character is irregular and shows several instances of parallel developments. A particularly large orbit is noted in taxa ranging from temnospondyls (Anderson et al, 2008; Sigurdsen & Bolt, 2010) to stem anthracosaurs such as *Silvanerpeton* (UMZC T.1317; Ruta & Clack, 2006), former "lepospondyls" (Carroll & Gaskill, 1978), *Diadectes* (Berman et al, 1998) and some crown amniotes (Laurin, 1993; Reisz et al, 2007).

Unambiguous: *Asaphestera intermedia* (0 -> 1), *Westlothiana lizziae* (0 -> 1), *Haptodus garnettensis* (0 -> 1), *Diadectes abistus* (0 -> 1), *Silvanerpeton miripedes* (0 -> 1),

Doleserpeton annectens + *Gerobatrachus hottoni* (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1). DELTRAN: *Belebey vegrandis* (0 -> 1).

68. Separately ossified postfrontal: absent (0); present (1).

Lea1998 (c.27), Rea2003 (c.57), RC2007 (c.56), ML2019 (c.45).

Lack of an ossified postfrontal is recorded in lysorophians (Pardo et al., 2016). Aïstopods show a single bone where postorbital and postfrontal would be expected (NMW1899.II.34; Carroll, 1998; Anderson, 2002; Pardo et al., 2017). Here, we follow Pardo et al., (2017), the only micro-CT reconstruction of an aïstopod, and Marjanovic & Laurin (2019), one of the most recent and most extensive tetrapod phylogenies, in considering that single bone to be a postorbital. Therefore, aïstopods are scored as absent for a postfrontal.

ACCTRAN: Aïstopoda (1 -> 0), Nectridea (0 -> 1). DELTRAN: *Brachydectes newberryi* (1 -> 0), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0).

69. Large, concave notch in posterior/ventral margin of postfrontal to accommodate the postorbital: absent, posterior margin is smooth (0); present (1).

Hea2013 (c.9), Pea2017 (c.7).

A clear concavity in the posteroventral margin of the postfrontal is widespread across microsaurs (Carroll & Gaskill, 1978; Gee et al., 2019), many synapsids (Laurin, 1993; Bolt & Scott, 1995; Reisz et al., 2009), and is present in *Westlothiana*, although this is likely exaggerated due to breakage in the specimen. As it is inherently connected to the shape of the anterodorsal margin of the postorbital, it is closely related to the presence of a sigmoid anterodorsal margin of the postorbital (ch.59), which is a character that has traditionally been associated with microsaurs (Carroll & Gaskill, 1978). However, the two characters are not entirely co-distributed; a notch in the postfrontal is not always necessary for a sinusoidal margin of the postorbital, such as in microbrachomorph microsaurs (Carroll & Gaskill, 1978). There are other cases, too, where the two characters are not co-distributed; as such they are retained as two separate characters, and see ch.69 for further discussion.

Unambiguous: *Scincosaurus crassus* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (1 -> 0), Synapsida (0 -> 1), Varanopidae (1 -> 0), *Opisthodontosaurus carrolli* (0 -> 1), *Silvanerpeton miripedes* (0 -> 1).

70. Position of posteriormost extent of postfrontal relative to posteriormost extent of jugal: postfrontal posterior extent is anterior to jugal posterior extent (0); postfrontal posterior extent is approximately in line with, or posterior to, jugal posteriormost extent (1).

Rea2003 (c.59), RC2007 (c.58), ML2019 (c.46).

The distribution of the derived state of this character, in which the postfrontal extends proportionally significantly posteriorly appears to be incongruent as it is observed in a wide selection of taxa in multiple clades. A large postfrontal is associated with tuditanomorph microsaurs in which the postfrontal incorporates much of the temporal region (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2019; Gee et al., 2021). It is also present in some seymouriamorphs (Klembara, 1997; Berman et al., 2000), the nectridean *Diploceraspis* (Beerbower, 1963) and many stem and crown amniotes (e.g. Carroll, 1969; Gow, 1974; Reisz, 1977). This character, while related to the size of the jugal (ch.15, ch.16), the two are not entirely co-dependent. For example, in *Haptodus* the postorbital region of the jugal is short, at less than one-third of the cheek (Laurin, 1993) but in *Dimetrodon* the postorbital region of the jugal is almost half of the cheek (Romer et al., 1940). However, in both these taxa the postfrontal is small enough that it doesn't approach the posterior margin of the jugal, regardless of the size of the jugal itself. As such, these are retained as separate characters.

Unambiguous: *Diploceraspis sp.* (0 -> 1), Araeoscelidia (0 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1), *Paleothyris acadiana* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Aïstopoda (0 -> 1), *Lethiscus stocki* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (0 -> 1), *Pantylus cordatus* (1 -> 0), Seymouriamorpha (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0). DELTRAN: *Phlegethontia linearis* (0 -> 1), *Oestocephalus sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), *Hapsidopareion lepton* (0 -> 1), *Discosauriscus austriacus* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

71. Postfrontal - tabular contact: absent, parietal contacts postorbital or supratemporal is absent (0); present (1).

Jenkins et al. 2025 (c.384).

A contact between the postfrontal and the tabular is absent in all taxa in which a supratemporal is present. Amongst those in which a supratemporal is lost, most microsaurs have a contact between the postfrontal and the tabular (Carroll & Gaskill, 1978).

Unambiguous: *Scincosaurus crassus* (0 -> 1), *Recumbirostra*(0 -> 1).

72. Postfrontal - jugal contact: absent, postorbital contributes to orbit margin (0); present, excluding postorbital from orbit margin (1).

Novel

In a small number of taxa, including some nectrideans Douthitt, 1917; Beerbower, 1963), the postfrontal and jugal obscure the postorbital from contacting the orbit margin.

Unambiguous: *Adelogyrinus simorhynchus* (0 -> 1), *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1), *Oestocephalus sp.* (0 -> 1).

73. Postfrontal, anterior process: short, does not extend anteriorly more than orbital midlength (0), long, extends anteriorly forming the dorsal surface of the orbit for more than half of its length (1)

This study.

The anterior process of the postfrontal of most taxa within this matrix, including most crown-group tetrapods (e.g., *Dendrerpeton,* Arbez et al. 2022), is reduced and does not extend further than orbital midlength in lateral view (State 0). In contrast, many stem tetrapods including whatcheerids (e.g., *Pederpes*, Clack and Finney 2005), embolomeres (*Eoherpeton*, Porro et al. 2024), adelospondylids (Andrew and Carroll 1992), and *Westlothiana* bear an elongate anterior process which may extend anterior to the orbit in lateral view (State 1).

Unambiguous: Baphetidae + *Silvanerpeton* + *Caerorachis* + *Westlothiana* + *Utaherpeton* + Aistopoda + Tetrapoda (0 → 1), *Westlothiana* + *Utaherpeton* (1 → 0).

74. Postfrontal, lateral margin: narrow, contributing to the concave rim of the orbit (0), laterally expanded forming a supraorbital shelf (1).

75. Separately ossified postorbital: absent (0); present (1).

A2001 (c.31), Rea2003 (c.75), RC2007 (c.77), ML2019 (c.60), Hea2013 (c.45), Pea2017 (c.41). Modified from a division of LR1997 (c.28), Lea1998 (c.28)

The single bone in the position of the postfrontal and postorbital in aïstopods (Carroll, 1998; Anderson, 2002; Pardo et al., 2017) is considered to be a postorbital, as per Pardo et al., (2017) and Marjanovic & Laurin (2019), and so they are scored as state 1 for this character. See ch.59 for further discussion.

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0).

76. Postorbital shape: irregularly polygonal, without a clearly defined shape (0); broadly triangular shape, narrowing to a distinct point posteriorly/anteroposteriorly (1).

Modified from Rea2003 (c.78), RC2007 (c.80), Cea2016 (c.47), Cea2019 (c.47), ML2019 (c.63), Hea2013 (c.48), Pea2017 (c.44).

The shape of the postorbital may appear irregular in many deeper stem tetrapod taxa such as Pederpes (Clack & Finney, 2005) and *Greererpeton* (Smithson, 1981).In most crown tetrapods, the postorbital is more triangular in shape, and tapers posteriorly or posterodorsally to a very clearly defined point, including temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), anthracosaurs (Panchen, 1977; Holmes, 1989) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005). Within a small number crown amniotes and some diadectamorphs and former "lepospondyls", the clearly defined shape is subsequently lost and the postorbital is irregular in shape, such as *Petrolacosaurus* (Reisz, 1977), *Casea* (Olson et al, 1968), and *Diadectes* (Berman et al, 1998), most nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009) and some microsaurs (Carroll & Gaskill, 1978).

Unambiguous: *Keraterpeton galvani* (0 -> 1), *Phlegethontia linearis* (0 -> 1), *Tuditanus punctulatus* (0 -> 1), *Llistrofus pricei* (0 -> 1), *Casea broilii* (1 -> 0), *Haptodus garnettensis* (1 -> 0), *Petrolacosaurus kansensis* (1 -> 0), *Diadectes abistus* + *Orobates pabsti* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0), Captorhinidae (1 -> 0). DELTRAN: Tetrapoda (0 -> 1), *Youngina capensis* (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0).

77. Postorbital width (measured as maximum dorsal to ventral distance) relative to maximum anteroposterior orbit width: postorbital smaller (0); postorbital larger (1).

Modified from Rea2003 (c.80), RC2007 (c.82), Cea2016 (c.48), Cea2019 (c.48), ML2019 (c.65).

This and the following character are modified from the same characters in previous analyses, combining them and then dividing them in a different way. Previously these characters were ambiguous as they did not define the specific dimensions of the postorbital that they were referring to. As such, this and the following character have been rewritten for clarity of scoring. A relatively tall postorbital (state 1) occurs in the stem tetrapods *Baphetes* (Beaumont, 1977) and *Greererpeton* (Smithson, 1981), the temnospondyl *Edops* (Romer & Witter, 1942) and the former "lepospondyls" *Pantylus* (Carroll & Gaskill, 1978), *Scincosaurus* (Milner & Ruta, 2009) and *Diplocaulus* (Douthitt, 1917). Most of the former "lepospondyls" in which this occurs are nectrideans.

Unambiguous: *Diplocaulus sp.* (0 -> 1), *Scincosaurus crassus* (0 -> 1), *Pantylus cordatus* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Tetrapoda (1 -> 0). DELTRAN: *Baphetes sp.* (0 -> 1), *Greererpeton burkemorani* (0 -> 1).

78. Postorbital length (measured as maximum anterior to posterior distance) relative to maximum anteroposterior orbit width: postorbital smaller or equal (0); postorbital larger (1).

Modified from Rea2003 (c.80), RC2007 (c.82), Cea2016 (c.48), Cea2019 (c.48), ML2019 (c.65).

The distribution of this character is similar to that of the previous character, as both are characters concerning the size of the postorbital. However, there are some differences, and anterior-posterior elongation of the postorbital (which is covered in this character) occurs with a somewhat different distribution as dorsal-ventral elongation of the postorbital (which is covered in the previous character). Some taxa, such as *Baphetes* (Beaumont, 1977), *Greererpeton* (Smithson, 1981), *Edops* (Romer & Witter, 1942) and *Diplocaulus* (Douthitt, 1917) demonstrate a general enlargement of the postorbital, and therefore are scored as state 1 in both this and the previous character. Other taxa, such as the microsaur *Microbrachis* (Carroll & Gaskill, 1978), the diadectamorph *Limnoscelis* (Romer, 1946) and the varanopid *Aerosaurus* (MCZ4380; Langston & Reisz, 1981) show an anteroposterior elongation of the postorbital (state 1), but the postorbital is not sufficiently dorsoventrally tall to score state 1 in the previous character.

Unambiguous: *Diplocaulus sp.* (0 -> 1), *Microbrachis pelikani* (0 -> 1), *Aerosaurus wellesi* (0 -> 1), *Youngina capensis* (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Tetrapoda (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), *Baphetes sp.* (0 -> 1), *Greererpeton burkemorani* (0 -> 1).

79. Postorbital, anterodorsal process: absent, postorbital bears a smooth, straight or gently curved margin (0); present, giving the dorsal margin of the postorbital a distinct sigmoid shape (1).

Rea2003 (c.82), RC2007 (c.84), ML2019 (c.67).

This character describes a curve observed in the anteromedial margin of the postorbital to produce a somewhat S-shaped profile. It consists of a clear dorsal or anterodorsally directed bump, then the margin descends anteriorly towards the orbit. This character is traditionally associated with microsaurs (Carroll & Gaskill, 1978), as described in ch.60, but it is also present in araeoscelidians (Reisz, 1977; Reisz et al., 1984) and in most synapsids (e.g. Laurin, 1993; Bolt & Scott, 1995; Reisz et al., 2009; Campione & Reisz, 2010). This character is somewhat correlated with ch.60, which describes a concave notch in the postfrontal for the postorbital, as the sigmoid margin of the postorbital (state 1 of this character) must be accommodated somewhere. However, there are cases where a sigmoid margin (state 1 of this character) can occur without a notch in the postfrontal. This is most clearly demonstrated in *Petrolacosaurus* (Reisz, 1977), in which the postorbital shows a dorsal sigmoid margin, but

the raised portion of the margin is not encompassed by the postfrontal, but instead is interspersed in between the postfrontal and the parietal.

Unambiguous: *Youngina capensis* (0 -> 1), *Opisthodontosaurus carrolli* (0 -> 1). ACCTRAN: Amniota (0 -> 1), Neoreptilia (1 -> 0). DELTRAN: Synapsida (0 -> 1).

80. Postorbital - supratemporal contact: absent (0); present (1); supratemporal absent (inapplicable).

This contact occurs in anthracosaurs (Panchen, 1977; Holmes, 1989) and diadectamorphs (Romer, 1946; Berman et al, 1998; 2004), amongst a large variety of taxa. Amongst those that retain a supratemporal that doesn't contact the postorbital, it can be because of a parietal-squamosal contact, such as in *Captorhinus* (Fox & Bowman, 1966), temporal fenestration such as in *Petrolacosaurus* (Reisz, 1977), or the presence of an intertemporal blocking the contact, such as in seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Aïstopoda (1 -> 0), Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 0), *Dendrerpeton helogenes* (1 -> 0). ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), Sphenacodontidae (0 -> 1), Reptilia (0 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0). DELTRAN: Edaphosauridae + Sphenacodontia (1 -> 0), *Dimetrodon sp.* (0 -> 1), Araeoscelidia (1 -> 0), *Youngina capensis* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (1 -> 0).

81. Postorbital - tabular contact: supratemporal absent and contact absent (0); contact present (1); supratemporal present (inapplicable).

Novel

A contact between the postorbital and tabular is never present when a supratemporal is present. Amongst taxa in which a supratemporal is absent, in most microsaurs, the postorbital extends posteriorly to contact the tabular (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 22019; 021). In most other former "lepospondyls", including a small number of microsaurs such as *Hyloplesion* and *Microbrachis* (Carroll & Gaskill, 1978), as well as diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018), the parietal contacts the squamosal anterior to the tabular, preventing the postorbital from extending posteriorly. As such, when a supratemporal is present, this character is scored as inapplicable so that this character distinguishes only between the condition in most microsaurs and the condition in nectrideans.

Unambiguous: *Scincosaurus crassus* (0 -> 1), *Recumbirostra*(0 -> 1), *Hapsidopareion lepton* (1 -> 0), *Youngina capensis* (0 -> 1).

82. Postorbital, free dorsal margin: absent (0); present (1).

FB2020 (c.75).

This character is one of several novel characters introduced by Ford & Benson (2020) to tackle the scoring of characters relating to temporal fenestration, and in particular the presumed homology of fenestrae in distantly related taxa. In previous analyses, temporal fenestration has been typically scored by characters relating to the presence or absence of both an upper and lower temporal fenestra separately (e.g. Gauthier et al, 1988; Laurin & Reisz, 1995). Here, we follow the characters of Ford & Benson (2020). A free dorsal margin of the postorbital, associated with the presence of two temporal fenestrae, is found most taxa that are traditionally recognised as 'diapsids' Laurin & Reisz, 1995), including araeoscelidians (Reisz, 1977; Reisz et al, 1984) and *Youngina* (Gow, 1974) in the current dataset.

Unambiguous: Araeoscelidia (0 -> 1), *Youngina capensis* (0 -> 1).

83. Jugal, free posterior margin: absent (0); present (1)

FB2020 (c.76).

This is the second character from Ford & Benson (2020) relating to temporal fenestration (see ch.72). A free posterior margin of the jugal is associated with the presence of the lower temporal fenestra, and is widespread across crown amniotes, including all included synapsids (e.g. Romer et al, 1940; Bolt & Scott, 1995; Modesto, 1995), former "parareptiles" (Gow, 1972; Reisz et al, 2007; Modesto et al, 2015), and *Youngina* (God, 1974). The condition is present in the araeoscelidian *Petrolacosaurus* (Reisz, 1977) but not *Araeoscelis* (Reisz et al, 1984; MCZ4380) in which the single temporal fenestra occupies a particularly dorsal position. It is also present in aïstopods, and the microsaurs *Hapsidopareion* (Carroll & Gaskill, 1978) and *Llistrofus* (Gee et al, 2019).

Unambiguous: Aïstopoda (0 -> 1), *Hapsidopareion lepton* (0 -> 1), Amniota (0 -> 1), *Araeoscelis gracilis* (1 -> 0).

84. Parietal, free lateral margin: absent (0); present (1).

FB2020 (c.95).

This is the third character from Ford & Benson (2020) relating to temporal fenestration (also see ch.72 and ch.73). A free lateral margin of the parietal is associated with the presence of an upper temporal fenestra, such as in *Petrolacosaurus* (Reisz, 1977) and neodiapsids such as *Youngina* (Gow, 1974) but is also present in other amniote taxa that have an enlarged single temporal fenestra, such as *Edaphosaurus* (Romer & Price, 1940; Modesto, 1995). State 1 is

also present in the aïstopod and lysorophians, which are characterised by skulls with reduced ossification (Pardo et al, 2016; Pardo et al, 2017).

Unambiguous: *Edaphosaurus boanerges* (0 -> 1), Araeoscelidia (0 -> 1), *Youngina capensis* (0 -> 1), *Orovenator mayorum* (0 -> 1). ACCTRAN: Nectridea (1 -> 0). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1).

85. Height of ventral temporal (=zygomatic) bar (complete or partially complete): dorsoventrally narrow, occupying less than 20% of postorbital skull height (0); dorsoventrally deep, occupying more than 20% of skull height (1); ventral temporal bar absent (inapplicable).

FB2020 (c.74). Modified from L1991 (c.B4), D1998 (c.32), RD2003 (c.18), M2004 (c.91), Rea2010 (c.41), Eea2014 (c.40).

This character is taken from Ford & Benson (2020) to help distinguish between different clades traditionally recognised as crown amniotes, or close to the amniote crown. State 1, a dorsoventrally deep ventral temporal bar, is generally present across synapsids (e.g. Romer & Price 1940; Brocklehurst et al, 2016; Mann & Paterson, 2020) and in *Petrolacosaurus* (Reisz, 1977), with a small number of reversals. Total-clade reptiles tend to show a narrower ventral temporal bar (state 0), although *Milleretta* shows state 1 during late ontogeny(Gow, 1972). Within aïstopods, *Lethiscus* has a less open postorbital skull than other aïstopods (Pardo et al, 2017) and is therefore scored as state 1.

Unambiguous: *Lethiscus stocki* (0 -> 1), Synapsida (0 -> 1), Varanopidae (1 -> 0), *Haptodus garnettensis* (1 -> 0), *Milleropsis pricei* (0 -> 1).

86. Jugal, anteroposterior thickness of dorsal ramus (forming postorbital bar): narrow (0); broad, temporal fenestra only weakly emarginates the jugal (1); inapplicable, temporal fenestration absent or jugal lacks dorsal ramus (inapplicable).

B2012 (c.73), FB2020 (c.81). Modified from Mea2008 (c.20).

This character describes the condition in caseasaurs and closely related taxa, in which the jugal dorsal ramus is thick anteroposteriorly, relative to the size of the temporal fenestra. In other taxa, it tends to narrow to a splinter-like thickness. State 1 also occurs in *Milleretta* (Gow, 1972).

Unambiguous: Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), *Milleropsis pricei* (0 -> 1). ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0). DELTRAN: Amniota (1 -> 0).

87. Jugal, concave ventral margin: absent (0), present (1).

88. Squamosal contribution to postemporal fenestra: absent (0); present (1); posttemporal fenestra absent (inapplicable).

FB2020 (c.94), LR1995 (c.26), DR1997 (c.36), MR2006 (c.49), T2006 (c.26), Tea2012 (c.25), LP2017 (c.25).

In captorhinids (Fox & Bowman, 1966), *Paleothyris* (Carroll, 1969) and *Hylonomus* (Carroll, 1964), as well as several crown amniotes, such as the synapsid *Varanosaurus* (Bolt & Scott, 1995), and the reptiles *Youngina* (Gow, 1974) and *Belebey* (Reisz et al., 2007), the squamosal extends onto the occiput and contributes to part of the margin of the posttemporal fenestra.

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), .Synapsida (1 -> 0), *Milleropsis pricei* (1 -> 0). ACCTRAN: *Hapsidopareion lepton* (0 -> 1). DELTRAN: *Hapsidopareion lepton* (0 -> 1).

89. Squamosal - jugal contact beneath temporal fenestra: absent, quadratojugal contributes to margin of fenestra (0); present (1); temporal fenestra absent (inapplicable).

Modified from FB2020 (c.90)

In Ford & Benson (2020) there are two characters concerning the contact of the squamosal and jugal. They scored separately whether or not the squamosal contacted the posterodorsal margin of the jugal (FB2020 c.89) and whether or not the squamosal contacted the posteroventral margin of the jugal (FB2020 c.90). The latter of these characters also describes whether or not the quadratojugal enters the temporal fenestra. Here, the wording is simplified for the sake of clarity, and the character is specified to describe whether or not the quadratojugal entered the temporal fenestra.

Unambiguous: *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1), Synapsida (0 -> 1), *Milleropsis pricei* (0 -> 1). ACCTRAN: Varanopidae (1 -> 0), Caseidae (1 -> 0). DELTRAN: *Aerosaurus wellesi* (1 -> 0), *Casea broilii* (1 -> 0).

90. Separately ossified jugal: absent (0); present (1).

Rea2003 (c.88), RC2007 (c.90), ML2019 (c.71). Modified from a division of LR1997 (c.30), Lea1998 (c.30).

Loss of a separately ossified jugal occurs within lysorophians (Wellstead, 1991; Pardo & Anderson, 2016).

Unambiguous: *Brachydectes newberryi* (1 -> 0).

91. Maximum depth of jugal measured beneath orbit midpoint, relative to maximum anteroposterior orbit diameter: smaller than one-third of orbit diameter, tapers to a point beneath orbit (0); between one-third and one-half of orbit diameter (1); equal to or larger than one-half of orbit diameter (2).

Rea2003 (c.91), Cea2019 (c.17), RC2007 (c.93), ML2019 (c.74), Cea2016 (c.17), Kea2014 (c.34)

The suborbital process of the jugal tapers to a point anteriorly in most ingroup taxa, and therefore the maximum dorsoventral depth of the jugal (from the margin of the orbit to its ventral edge) is smaller than 1/3 of the maximum diameter of the stem tetrapods, the jugal can extend anterior to the orbit (see ch.84), and therefore the jugal does not typically taper to a point below the orbit, but the suborbital ramus exhibits different depths in anthracosaurs and stem tetrapods, and therefore states 1 and 2 are included here to differentiate between them. In anthracosaurs (Panchen, 1977; Holmes, 1989), the jugal extends anterior to the orbit, but the suborbital process remains relatively narrow, being between 1/3 and 1/2 of the orbit diameter in height (state 1). This contrasts the condition in deeper stem taxa such as *Baphetes* (Beaumont, 1977) and *Greererpeton* (Smithson, 1981), in which the jugal suborbital process is larger than half of the orbit diameter (state 2).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 2), *Pantylus cordatus* (0 -> 1), Sphenacodontidae (0 -> 2), *Varanosaurus acutirostris* (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Solenodonsaurus janenschi* (0 -> 1). ACCTRAN: Tetrapoda (2 -> 0), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1), *Edops craigi* (0 -> 2). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 0), Diplocaulidae (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (2 -> 1), Temnospondyli except *Edops craigi* (2 -> 0).

92. Length of postorbital region of jugal relative to suborbital region of jugal: postorbital region is shorter (0); suborbital region is shorter (1).

Novel

The suborbital and postorbital regions are measured from a vertical line tangential to the posteriormost point of the orbit. In taxa in which there is a substantial suborbital ramus of the jugal (ch.84), the suborbital region is often longer than the postorbital region, such as is the case in *Anthracosaurus* (Panchen, 1977) or *Ariekanerpeton* (Klembara & Ruta, 2005). Conversely, in taxa in which the jugal forms a substantial portion of the cheek and therefore extends posterior to the postorbital (ch.83), the postorbital region is often longer than the suborbital region, such as in the temnospondyl *Dendrerpeton* (Arbez et al., 2022). However, these characters are not completely codependent on each other. For example, in microsaurs, the jugal typically forms a substantial part of the cheek, and the postorbital region is longer than the suborbital region, but the postorbital is also expanded more posteriorly than most other taxa, and thus the jugal does not extend more posteriorly than the postorbital, such as in

Huskerpeton (Huttenlocker et al., 2013) or *Euryodus* (Gee et al., 2021). As such, this character, ch.83 and ch.84 are retained as separate characters.

Unambiguous: Aïstopoda (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Solenodonsaurus janenschi* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). DELTRAN: *Dendrerpeton helogenes* (0 -> 1).

93. Shape of posterior margin of jugal: sloping anteroventrally to posterodorsally, whether concave or straight (0); straight, vertical margin (1); margin slopes anterodorsally to posteroventrally, whether concave or straight, but ventrally does not form a distinct posterior process (2); distinctly triradiate, with an anterodorsal to posteroventrally sloping concave margin, but ventrally forms a distinct posterior process (3).

Novel

State 3 describes the condition observed in many derived amniotes, in which there is a concave posterior margin that slopes anterodorsally to posteroventrally (e.g. Reisz, 1977; Bolt & Scott, 1995; Reisz & Dilkes, 2003; Reisz et al., 2009), but unlike in other taxa showing a similarly concave margin (e.g. *Ariekanerpeton*, Klembara & Ruta, 2005; *Silvanerpeton*, Ruta & Clack, 2006), the concavity is restricted to the dorsal part of the posterior margin, and ventral to this the posterior margin is stretched out into a thick, distinct posterior process that does not taper. As such, state 3 is generally correlated with having a free posterodorsal margin of the jugal that opens into a temporal fenestra. However, this state is retained separately to scoring of temporal fenestration as there are two taxa noted in this study that have a triradiate, amniote-like jugal but do not have temporal fenestration, namely *Orobates* (MNG 8760, 14257) and *Opisthodontosaurus* (Reisz et al, 2015).

Unambiguous: *Hapsidopareion lepton* (1 -> 0), Amniota (2 -> 3), *Milleropsis pricei* (3 -> 1), *Orobates pabsti* (2 -> 3), *Discosauriscus austriacus* (2 -> 1), *Archeria crassidisca* (2 -> 1), *Dendrerpeton helogenes* (2 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 2), *Lethiscus stocki* + *Phlegethontia linearis* (2 -> 3), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (3 -> 0). DELTRAN: *Lethiscus stocki* (2 -> 3), *Westlothiana lizziae* (2 -> 0), *Belebey vegrandis* (3 -> 0), *Whatcheeria deltae* (2 -> 1).

94. Posteriormost extent of the jugal relative to posteriormost extent of the postorbital: Not posterior or in line with posterior margin of postorbital (0), extending clearly beyond level of postorbital (1), jugal absent (inapplicable).

Modified from Cea2019 (c.243).

This character has a wide, disparate distribution. The character has been completely reworded from Clack et al. (2019 c.243) so that it is clearer how to score this character if the posterior extension is similar in both bones. In most included taxa, the scores for this character are consistent with the scores for ch.83, as a jugal that takes up a large proportion of the cheek is also likely to extend more posteriorly, relative to the postorbital. However, in some taxa such as *Adelogyrinus* (Andrews & Carroll, 1991), *Dimetrodon* (Romer et al., 1940) and many microsaurs (Carroll & Gaskill, 1978) the jugal is large but the postorbital is also large, and so the jugal does not terminate posteriorly to the postorbital. In the seymouriamorphs *Discosauriscus* (Klembara, 1997) and *Ariekanerpeton* (Klembara & Ruta, 2005) both the jugal and postorbital are short, so the jugal does not extend to more than one-third of the cheek length, but still terminates posterior to the postorbital.

Unambiguous: Amniota + Diadectamorpha + Microsauria (1 -> 0). *Acherontiscus caledoniae* (0 -> 1), *Keraterpeton galvani* (0 -> 1), *Lethiscus stocki* (0 -> 1), *Varanops brevirostris* (0 -> 1), *Haptodus garnettensis* (0 -> 1), *Edaphosaurus boanerges* (0 -> 1), *Varanosaurus acutirostris* (0 -> 1), *Opisthodontosaurus carrolli* (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Seymouria sanjuanensis* (1 -> 0), *Archeria crassidisca* (1 -> 0), *Balanerpeton woodi* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1). DELTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1).

95. Jugal anteriormost extent beneath orbital margin: jugal terminates posterior to or at orbit midlength (0); jugal terminates anterior to orbit midlength but posterior to anteriormost extent of orbit (1); jugal terminates anterior to orbit (2) (ordered).

Modified from Cea2016 (c.18), Cea2019 (c.18)

This replaces a character concerning whether or not the jugal contributed more than a third or not to the orbital margin (Clack et al., 2016 c.18; Clack et al., 2019 c.18). The first two states in the version of the character used here are almost perfectly co-distributed with the original character as in almost every case where the jugal contributes less than a third of the orbital margin, it also terminates posterior to the orbit midlength. However, this further distinction of states accounts for more division amongst those taxa with large jugals contributing large portions of the orbit margin, and specifically accounts for the condition in anthracosaurs in which the jugal extends far anterior to the orbit (Panchen, 1977; Holmes, 1989). As stated previously, although the distribution is related to ch.79 (the dorsoventral depth of the jugal ventral to orbit midlength), but this character and ch.79 are not perfectly co-distributed, and so are retained as separate characters.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1), *Diplocaulus sp.* (1 -> 2), *Scincosaurus crassus* (1 -> 2), *Pantylus cordatus* (1 -> 2), Sphenacodontia (1 -> 2), *Varanosaurus acutirostris* (1 -> 2), Temnospondyli except *Edops craigi* (2 -> 1). ACCTRAN: *Diplocaulus sp.* (1 -> 2),

Caseasauria + *Echinerpeton intermedium* (1 -> 0). DELTRAN: Diplocaulidae (0 -> 1), *Echinerpeton intermedium* (1 -> 0).

96. Jugal - squamosal contact: absent, typically due to ventral emargination or temporal fenestration (0); present (1).

A lack of a contact between the jugal and the squamosal is observed where there is some degree of ventral emargination in the microsaurs *Llistrofus* (Gee et al, 2019) and *Hapsidopareion* (Carroll & Gaskill, 1978), or a temporal fenestra such as in *Lethiscus* (Pardo et al, 2017) or *Petrolacosaurus* (Reisz, 1977).

Unambiguous: *Hapsidopareion lepton* (1 -> 0), Caseidae (1 -> 0), *Petrolacosaurus kansensis* (1 -> 0), *Youngina capensis* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), *Phlegethontia linearis* (0 -> 1), Varanopidae (1 -> 0), Edaphosauridae (1 -> 0). DELTRAN: *Lethiscus stocki* (1 -> 0), *Oestocephalus sp.* (1 -> 0), *Aerosaurus wellesi* (1 -> 0), *Edaphosaurus boanerges* (1 -> 0).

97. Maxilla - quadratojugal contact: absent, jugal makes contribution to ventral skull margin (0); present, excluding jugal from ventral skull margin (1).

Rea2003 (c.89), RC2007 (c.91), Cea2016 (c.22), Cea2019 (c.22).

In several taxa, particularly stem tetrapods such as *Greererpeton* (Smithson, 1981) and anthracosaurs (Panchen, 1977; Holmes, 1989, and temnospondyls such as *Doleserpeton* (Sigurdsen & Bolt, 2010), the maxilla extends posteriorly sufficiently to contact the quadratojugal.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0), Adelospondyli (0 -> 1), *Oestocephalus sp.* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), Caseidae (1 -> 0), *Captorhinus aguti* (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1). DELTRAN: *Belebey vegrandis* (0 -> 1).

98. Jugal - prefrontal contact: absent, lacrimal makes contribution to orbit margin (0); present, excluding lacrimal from orbit margin (1); jugal and lacrimal do not contact, maxilla enters orbit (inapplicable).

Novel

There are no cases where the maxilla enters the orbit and the jugal still contacts the prefrontal. As such, if the maxilla enters the orbit then this character is scored as inapplicable, so that the scoring of this character is kept separate from ch.46.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Diplocaulus sp.* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: Embolomeri + *Chroniosaurus dongusensis* (0 -> 1), *Anthracosaurus russelli* (1 -> 0). DELTRAN: *Archeria crassidisca* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1).

99. Jugal - quadratojugal contact: absent, due to ventral emargination of the cheek (0); present (1).

Rea2003 (c.112), RC2007 (c.117), ML2019 (c.98), Hea2013 (c.225), Pea2017 (c.183).

This distribution of states in this character is related to the distribution of states in ch.85. There are, however, some differences and so they are scored separately. Ch.85, a contact between the jugal and squamosal, is sometimes absent due to ventral emargination, as seen in the microsaurs *Llistrofus* (Gee et al, 2019) and *Hapsidopareion* (Carroll & Gaskill, 1978). However, an absence of a contact between the jugal and squamosal is also sometimes due to temporal fenestration, but such temporal fenestration does not prevent a jugal-quadratojugal contact (this character). In addition, in edaphosaurids and sphenacodontids (Romer et al., 1940; Laurin, 1993; Modesto, 1995), there is a partial ventral emargination in addition to the temporal fenestra which prevents the jugal from contacting the quadratojugal.

Unambiguous: *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0). *Micraroter erythrogeois* (1 -> 0), *Hapsidopareion lepton* (1 -> 0).

100. Separately ossified quadratojugal: absent (0); present (1).

LR1997 (c.35), Lea1998 (c.35), A2001 (c.13), Rea2003 (c.95), RC2007 (c.97), ML2019 (c.77), Hea2013 (c.18), Pea2017 (c.15).

A lack of a quadratojugal is observed in lysorophians (Pardo et al., 2016). It is also missing in the microsaur *Hapsidopareion* (Carroll & Gaskill, 1978). The element that could be considered a squamosal of *Phlegethontia* is better considered to be a quadratojugal by comparison with other aïstopod taxa (Anderson, 2002).

Unambiguous: *Procynosuchus delaharpeae* (1 -> 0). ACCTRAN: .Synapsida (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0). DELTRAN: Varanopidae (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1).

101. Maximum dorsoventral depth of quadratojugal relative to 1/4 of the maximum dorsoventral depth of squamosal: quadratojugal is smaller than 1/4 of squamosal (0); quadratojugal is larger than 1/4 of squamosal (1).

RC2007 (c.98), ML2019 (c.78). Modified from Rea2003 (c.96), which was improved in RC2007.

The depth of the bones is measured, in lateral aspect, between their ventral edge and the dorsal most part of their external surface. A dorsoventrally narrow quadratojugal is present in all synapsids included in this analysis in which it can be discerned (e.g. Olson et al., 1968; Bolt & Scott, 1995; Modesto, 1995), and is also known in seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005) and derived temnospondyls (Anderson et al., 2008; Sigurdsen & Bolt, 2010; Arbez et al., 2022). Some former "lepospondyls", including the nectridean *Diploceraspis* (Beerbower, 1963) and some microsaurs (Carroll & Gaskill, 1978), also show a narrow quadratojugal.

Unambiguous: Synapsida (1 -> 0), *Opisthodontosaurus carrolli* (1 -> 0), Seymouriamorpha (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (1 -> 0). ACCTRAN: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0). DELTRAN: *Diploceraspis sp.* (1 -> 0), *Cardiocephalus sp.* (1 -> 0).

102. Dorsalmost extent of quadratojugal relative to dorsalmost extent of maxilla: lower than dorsalmost extent of maxilla (0); higher than dorsal most extent of maxilla (1).

Novel

In stem tetrapods, the quadratojugal extends dorsally to a point at least as high as the dorsal margin of the maxilla (Beaumont, 1977; Smithson, 1981; Rawson et al., 2021). A large number of stem tetrapods across many disparate clades show a dorsal extent of the maxilla that exceeds the dorsal extent of the quadratojugal including temnospondyls (e.g. Sigurdsen & Bolt, 2010; Arbez et al., 2022), *Anthracosaurus* (Panchen, 1977), seymouriamorphs (Klembara, 1977; Klembara & Ruta, 2005), former "lepospondyls" (e.g. Beerbower, 1963; Carroll & Gaskill, 1978), diadectamorphs (Romer, 1946; Berman et al., 1998) and many crownward stem and crown amniotes (e.g. Fox & Bowman, 1966; Carroll, 1969; Gow, 1972; Gow, 1974; Laurin, 1993; Brocklehurst et al., 2016).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), *Aerosaurus wellesi* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), Seymouriamorpha (1 -> 0), *Anthracosaurus russelli* (1 -> 0), Temnospondyli (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (1 -> 0), *Huskerpeton englehorni* (0 -> 1). DELTRAN: Diplocaulidae (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0).

103. Quadratojugal anteriormost extent: not reaching level of posteriormost margin of orbit (0); reaching posteriormost margin of orbit (1).

LR1995 (c.23).

This character is one of several characters included in Laurin & Reisz (1995) that defined various amniote clades in their included taxa. It is included here as some traditional groups recovered in that study are not recovered here. Laurin & Reisz (1995) comment that the quadratojugal of diadectamorphs is short, as is the case in “Eureptilia”, a paraphyletic clade encompassing captorhinids, araeoscelidians and younginiforms. However, Laurin & Reisz note that this character is of uncertain polarity, due to the presence of a longer quadratojugal that reaches the orbit, in seymouriamorphs, most synapsids, and many former "parareptiles".

Unambiguous: *Varanosaurus acutirostris* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), *Gerobatrachus hottoni* (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1). DELTRAN: *Belebey vegrandis* (0 -> 1).

104. Squamosal posterodorsal margin shape: concave (0); sigmoid or approximately straight (1); convex (2).

Cea2016 (c.59), Cea2019 (c.59).

A clearly concave posterior margin of the squamosal is present in many taxa that have a posterior emargination of the skull, such as some temnospondyls (Milner & Sequeira, 1993; Arbez et al., 2022) or *Silvanerpeton* (Ruta & Clack, 2006). Embolomeres (Panchen, 1977; Holmes, 1989) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005), due to posterior emargination, have a short, shallowly concave section right at the dorsal end of the posterior margin of the squamosal. However, as this represents only a short section and most the posterior margin is straight, they are scored as having a straight margin (state 1).

Unambiguous: Amniota + Diadectamorpha + Microsauria (0 -> 1), *Brachydectes newberryi* (1 -> 0), *Keraterpeton galvani* (1 -> 0), *Phlegethontia linearis* (1 -> 0), *Westlothiana lizziae* (1 -> 2), *Diadectes abistus* (1 -> 0), *Gephyrostegus bohemicus* (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1), *Greererpeton burkemorani* (0 -> 2). ACCTRAN: Adelospondyli (1 -> 0), *Adelogyrinus* (0 -> 2), *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 2). DELTRAN: *Acherontiscus caledoniae* (1 -> 0), *Adelogyrinus simorhynchus* (1 -> 2), *Doleserpeton annectens* (0 -> 2).

105. Posterior margin of squamosal sloping anteroventrally to posterodorsally: not sloping, oriented vertically or sloping anterodorsally to posteroventrally (0); sloping anteroventrally to posterodorsally (1).

Rea2003 (c.84), RC2007 (c.86).

An overturned posterior squamosal margin, so that it slopes in the opposite direction than is typical for most tetrapods, is found in the lysorophian lepospondyl *Brachydectes* (Pardo &

Anderson, 2016), the microsaurs *Cardiocephalus* (Carroll & Gaskill, 1978) and *Euryodus* (Gee et al, 2021) and the synapsid *Procynosuchus* (Kemp, 1979).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Cardiocephalus sp. + Euryodus sp.* (0 -> 1), *Procynosuchus delaharpeae* (0 -> 1).

106. Anteriormost extent of the squamosal position relative to parietal mid-length, measured along anteroposterior axis of skull: posterior to parietal mid-length (0); level with or anterior to parietal mid-length (1).

Rea2003 (c.83), RC2007 (c.85), Cea2016 (c.62), ML2019 (c.68), Cea2019 (c.62).

In most ingroup taxa, the anteriormost part of the squamosal lies well in front of the midlength of the parietals. However, some former "lepospondyls" (e.g. Carroll & Gaskill, 1978; Pardo et al., 2017) and many synapsids (Olson et al., 1968; Laurin, 1993; Reisz & Fröbisch, 2014) show a posterior shift in the position of the anterior margin of the squamosal.

Unambiguous: *Tuditanus punctulatus* (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni + Micraroter erythrogeois + Hapsidopareion lepton* (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (1 -> 0), *Haptodus garnettensis* (1 -> 0), *Archaeovenator hamiltonensis* (1 -> 0), *Greererpeton burkemorani* (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (1 -> 0), Aïstopoda (1 -> 0).

107. Internal shelf of squamosal along which the quadrate articulates: absent (0); present (1).

Rea2003 (c.87), RC2007 (c.89), ML2019 (c.70), Hea2013 (c.37).

In nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), the ventral side of the squamosal sends a bony sheet, or strut, which provides support and buttressing for the pterygoid ramus of the quadrate and sometimes the quadrate ramus of the pterygoid. This feature is indeed widespread among early tetrapods, and is present in at least *Edops* (Romer and Witter 1942).

Unambiguous: Nectridea (0 -> 1).

108. Squamosal making contact with posterior corner of skull table: absent, posterior emargination present (0); present, squamosal contacts tabular, or supratemporal if this is forming posterior corner of skull table (1).

Novel

A contact between the squamosal and whichever elements make up the posterior corner of the skull table does not occur where there is a posterior embayment to the posterior margin of the skull, such as that in anthracosaurs (Panchen, 1977; Holmes, 1989) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), *Edops craigi* (0 -> 1), *Greererpeton burkemorani* (0 -> 1).

109. Parietal anterior margin position relative to orbit midlength: posterior to orbit midlength (0); level with orbit midlength (1); anterior to orbit midlength (2).(ordered).

Rea2003 (c.41), RC2007 (c.40), Cea2016 (c.40), Ml2019 (c.33), Cea2019 (c.40).

The position of the midlength of the orbit is measured along its greatest anteroposterior diameter.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Oestocephalus sp.* (0 -> 2).

110. Parietal length relative to width: less than two and a half times longer than wide (0); at least two and a half times longer than wide (1).

Rea2003 (c.43), RC2007 (c.42), ML2019 (c.35), Cea2019 (c.224).

The greatest anteroposterior length is measured, and the greatest lateral width. Ruta & Coates (2007) stated that the metric cut-off points used to discriminate between the two states are based upon the pattern of parietal elongation in the outgroup. Certain former "lepospondyls", as well as colosteids, show a return to plesiomorphic condition.

Unambiguous: *Adelogyrinus simorhynchus* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Aïstopoda (0 -> 1), Nectridea (1 -> 0). DELTRAN: *Brachydectes newberryi* (0 -> 1), Aïstopoda (0 -> 1).

111. Parietal width relative to frontal width: parietals narrower than frontals or equal in width (0); parietals wider than frontals (1).

Hea2013 (c.227), Pea2017 (c.185).

Unambiguous: *Adelogyrinus simorhynchus* (1 -> 0), *Tuditanus punctulatus* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0), *Edops craigi* (1 -> 0).

112. Parietal - parietal total width: shorter than the distance between the orbit posterior margin and skull posterior margin, measured along skull midline (0); longer than this distance (1).

Rea2003 (c.73), RC2007 (c.73), ML2019 (c.57), Cea2019 (c.231).

Unambiguous: Amniota + Diadectamorpha + Microsauria (0 -> 1) *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Llistrofus pricei* (1 -> 0), *Eothyris parkeyi* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), *Seymouria sanjuanensis* (0 -> 1). ACCTRAN: Edaphosauridae (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (1 -> 0), *Euconcordia cunninghami* (0 -> 1). DELTRAN: *Edaphosaurus* (1 -> 0), *Captorhinus aguti* (1 -> 0).

113. Width of anteriormost third of parietals: narrow anteriorly so that the width is not wider than frontals at the level of the frontal-parietal contact (0); do not narrow anteriorly, wider than frontals at this level (1).

Rea2003 (c.42), RC2007 (c.41), Cea2016 (c.41), ML2019 (c.34), Cea2019 (c.41).

State 0 of this character describes a particular condition in which the parietals narrow in their anterior third, towards the anterior contact with the frontals, so that they reach the same width as the frontals by their contact with the frontals. State 1 describes the case in which the parietals remain a relatively constant width along their entire length. Generally, within the ingroup taxa, the parietals narrow anteriorly (state 0), such as in *Westlothiana* or *Gephyrostegus* (Klembara et al, 2014), but there are several reversals to state 1, particularly within former "lepospondyls", such as *Hyloplesion* (Carroll & Gaskill, 1978), *Lethiscus* (Pardo et al., 2017) and *Acherontiscus* (Clack et al., 2019) and temnospondyls (Romer & Witter, 1942; Sigurdsen & Bolt, 2010; Arbez et al., 2022).

Unambiguous: *Acherontiscus caledoniae* (0 -> 1), *Brachydectes newberryi* (0 -> 1), *Milleropsis pricei* (0 -> 1), Diadectamorpha (0 -> 1), *Anthracosaurus russelli* (0 -> 1). ACCTRAN: *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1), Temnospondyli (0 -> 1), *Balanerpeton woodi* (1 -> 0), *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Diplocaulus sp.* (0 -> 1), *Lethiscus stocki* (0 -> 1), *Hyloplesion longicostatum* (0 -> 1), *Microbrachis pelikani* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1), *Doleserpeton annectens* (0 -> 1), *Edops craigi* (0 -> 1).

114. Pineal foramen: absent (0); present (1).

Hea2013 (c.54), Anderson2001 (c.38), LR1997 (c.15), L1998 (c.15), Rea2003 (c.106), ML2019 (c.91), Pea2017 (c.48).

A pineal foramen is present widely across the included taxa. However, it is absent in many former "lepospondyls", including the aïstopods *Oestocephalus* (Carroll, 1998) and *Phlegethontia* (NMW1899.IX.13b; Anderson, 2002), the lysorophian *Brachydectes* (Pardo et al., 2016), and the microsaurs *Pantylus* (Carroll & Gaskill, 1978) and *Huskerpeton* (Huttenlocker et al., 2013). A pineal foramen is absent in some, but not all, specimens of the microsaurs *Cardiocephalus* (Carroll & Gaskill, 1978) and *Euryodus* (Carroll & Gaskill, 1978; Gee et al., 2021).

Unambiguous: *Acherontiscus caledoniae* (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), Nectridea (0 -> 1), *Lethiscus stocki* (0 -> 1). DELTRAN: *Brachydectes newberryi* (1 -> 0), *Phlegethontia linearis* (1 -> 0), *Oestocephalus sp.* (1 -> 0).

115. Position of pineal foramen along anteroposterior length of parietals: posterior to midpoint (0); at midpoint (1); anterior to midpoint (2).(ordered).

Rea2003 (c.107), RC2007 (c.111), Cea2016 (c.166), Cea2019 (c.166), ML2019 (c.92). Modified from Pea2017 (c.249, c.250).

The position of the pineal foramen relative to the midpoint of the parietals is determined by comparing the length from the anterior tip of the foramen to the anterior tip of the parietals, and the posterior tip of the foramen to the posterior tip of the parietals. In those taxa in which these lengths are approximately equivalent, the pineal foramen is deemed to be at the midpoint. In stem tetrapods the pineal foramen occupies a relatively posterior position (Smithson, 1981; Rawson et al., 2021). In some temnospondyls, the pineal foramen is positioned more anteriorly, at the midpoint in *Dendrerpeton* (Arbez et al., 2022) and anterior to the midpoint in *Balanerpeton* (Milner & Sequeira, 1993). The pineal foramen is at the midpoint in anthracosaurs (Panchen, 1977; Holmes, 1989) and *Chroniosaurus* (Clack & Klembara, 2009), and the pineal foramen is anterior to the midpoint in seymouriamorphs (Klembara et al., 1997; Klembara & Ruta, 2005). Former "lepospondyls" typically show a more anterior position than the outgroup as well, with some taxa having a pineal foramen at the midpoint such as *Lethiscus* (Pardo et al., 2017), *Diploceraspis* (Beerbower, 1963) and *Utaherpeton* (Carroll et al., 1991), or anterior to the midpoint as in *Cardiocephalus* (Carroll & Gaskill, 1978), *Keraterpeton* (Milner, 2018) and *Diplocaulus* (Douthitt, 1917). Crownward stem amniotes and crown amniotes show a similar variety of states, with the pineal foramen positioned anterior to the midpoint in captorhinomorphs (Fox & Bowman, 1966; Reisz et al., 2016), at the midpoint in *Petrolacosaurus* (Reisz, 1977) and some synapsids (Olson et al., 1968; Reisz et al., 2009), and even posterior to the midpoint in most synapsids (e.g. Laurin, 1993; Bolt & Scott, 1995; Brocklehurst et al., 2016) and some former "parareptiles" (Gow, 1972; Reisz et al, 2007).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 2), *Utaherpeton franklini* (0 -> 1), Diplocaulidae (0 -> 2), *Diploceraspis sp.* (2 -> 1), *Asaphestera intermedia* (2 -> 1), *Micraroter erythrogeois* (2 -> 1),

Amniota (2 -> 0), *Procynosuchus delaharpeae* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Youngina capensis* (0 -> 2), Diadectamorpha (2 -> 1), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1). ACCTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1), Caseasauria + *Echinerpeton intermedium* (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1), *Balanerpeton woodi* (1 -> 2), *Doleserpeton annectens* (1 -> 0). DELTRAN: *Lethiscus stocki* (0 -> 1), Caseasauria (0 -> 1), *Balanerpeton woodi* (0 -> 2), *Dendrerpeton helogenes* (0 -> 1), *Gerobatrachus hottoni* (0 -> 1).

116. Size of the pineal foramen: small, less than 25% of mid-parietal length (0); large, at least 25% of mid-parietal length (1); pineal foramen absent (inapplicable).

FB2020 (c96). Modified from Gea1988 (c.17), Rea1992 (c.17), Bea1995 (c.22), M2004 (c.12), Rea2009 (c.84), Rea2010 (c.31), B2012 (c.35), Sea2018 (c.52).

An enlarged pineal foramen is present in various clades of crown amniotes. It is present in synapsids including caseasaurs (Olson et al., 1968; Reisz et al., 2009; Brocklehurst et al., 2016), *Varanosaurus* (Bolt & Scott, 1995) and the varanopid *Aerosaurus* (Langston & Reisz, 1981), as well as the parareptile *Belebey* (Reisz et al., 2007). It is also present in the diadectamorphs *Diadectes* (Berman et al., 1998) and *Orobates* (Berman et al., 2004).

Unambiguous: *Pantelosaurus saxonicus* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1). ACCTRAN: Synapsida (0 -> 1), *Varanops brevirostris* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1). DELTRAN: *Aerosaurus wellesi* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), *Varanosaurus acutirostris* (0 -> 1), *Belebey vegrandis* (0 -> 1).

117. Parietal - squamosal contact: absent (0); present (1). Inapplicable in taxa lacking an ossification of the temporal series.

Novel

There are several instances in which the parietal and squamosal contact each other. In nectrideans (e.g. Beerbower, 1963; Milner, 2018) both bones are part of the posterior extension of the skull that forms the tabular horn. In *Captorhinus* (Fox & Bowman, 1966), contact is allowed by the loss of the tabular. In *Dimetrodon* (Romer et al, 1940) and *Belebey* (Reisz et al, 2007), the postorbital is restricted to an anterior position and so does not contact any bones of the temporal series, allowing a contact between the parietal and the squamosal.

Unambiguous: Aïstopoda (0 -> 1), *Scincosaurus crassus* (1 -> 0), Aïstopoda (1 -> 0), Edaphosauridae + Sphenacodontia (0 -> 1), *Dimetrodon sp.* (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 1).

118. Parietal - postorbital contact: absent (0); present (1).

Often, the parietal and postorbital contact each other, such as in diadectamorphs (Berman et al., 1998; 2004) and most amniotes crownwards of diadectamorphs (e.g. Carroll, 1964; 1969; Reisz, 1977; Bolt & Scott, 1995; Reisz et al., 2007; Campione & Reisz, 2010; Modesto et al., 2015), but this isn't always the case. This could be because of the presence of an intertemporal (e.g. Panchen, 1977; Klembara, 1997) and in microsaurs it is because of a backwards extension of the postfrontal (Carroll & Gaskill, 1978).

Unambiguous: Amniota + Diadectamorpha + Microsauria (0 -> 1), *Scincosaurus crassus* (1 -> 0), *Recumbirostra* (1 -> 0), *Youngina capensis* (1 -> 0), *Greererpeton burkemorani* (0 -> 1).

119. Parietal - tabular contact: absent, postparietal contacts supratemporal (0); present (1).

Novel

Most taxa show a contact between the parietal and the tabular, regardless of the presence of a supratemporal, including in *Archeria* (Holmes, 1989), *Seymouria* (Berman et al. 1987) and *Gephyrostegus* (Klembara et al, 2014) which all retain an intertemporal and a supratemporal. In the outgroup taxa (Clack & Finney, 2005; Rawson et al., 2021), and other stem tetrapods (Beaumont, 1977; Smithson, 1981) and temnospondyls (e.g. Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010) there is a contact instead between the postparietal and the supratemporal.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Acherontiscus caledoniae* (1 -> 0), *Brachydectes newberryi* (1 -> 0), *Diadectes abistus* (1 -> 0).

120. Parietal, lateral extension in dorsal view at midlength: absent (0), present (1).

This study.

The parietal *Utaherpeton* (Carroll et al. 1991) bear a lateral process of the parietal at the level of the pineal foramen, giving the two parietals a half t-shape when seen in dorsal view (State 1).

Unambiguous: *Utaherpeton* $(0 \rightarrow 1)$. DELTRAN: *Westlothiana* and *Utaherpeton* + Aistopoda (0 to 1).

121. Separately ossified intertemporal: absent (0); present (1).

LR1997 (c.16), Lea1998 (c.16), Rea2003 (c.60), RC2007 (c.59), Kea2014 (c.23), Cea2016 (c.13), Cea2019 (c.13), Hea2013 (c.4). Modified from Pea2017 (c.4).

An absence of an ossified intertemporal occurs in many crown tetrapods, resulting from multiple independent evolutionary losses on the lissamphibian stem and amniote stem (Clack & Klembara, 2009; Sigurdsen & Bolt, 2010; Danto et al, 2012). Hence, the intertemporal is present in stem tetrapods including embolomeres (Panchen, 1977; Holmes, 1989), in seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005), and in early-diverging temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993). Within temnospondyls, in the taxon set studied here, it is only known to be absent in *Doleserpeton* and nectrideans, if they are indeed temnospondyls (Sigurdsen & Bolt, 2010).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0). ACCTRAN: *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Doleserpeton annectens* (1 -> 0).

122. Intertemporal size relative to supratemporal size: smaller than supratemporal (0); equal or larger than supratemporal (1), supratemporal or intertemporal absent (inapplicable).

Kea2014 (c.24), Cea2016 (c.14), ML2019 (c.49), Cea2019 (c.14)

This character exhibits a clear dichotomy in the states. In some stem tetrapods, such as *Greererpeton*, the intertemporal is a tiny element, particularly when compared to the supratemporal (Smithson, 1981), and in temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005), the intertemporal is still substantially smaller than the supratemporal, and approaches a maximum of half the size of the supratemporal in area. In anthracosaurs (Panchen, 1977; Holmes, 1989) and *Gephyrostegus* (Klembara et al., 2014) the two elements are roughly equivalent in area. Such a dichotomy has been previously noted in Marjanovic & Laurin (2019).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1); Seymouriamorpha (1 -> 0)

123. Intertemporal - squamosal contact: absent (0); present (1); intertemporal absent (inapplicable).

Novel

In taxa where this contact is absent, such as anthracosaurs (Panchen, 1977; Holmes, 1989), the postorbital contacts the supratemporal instead.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). DELTRAN: Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1).

124. Separately ossified supratemporal: absent (0); present (1).

LR1997 (c.17), Lea1998 (c.17), A2001 (c.2), RC2003 (c.63), Rea2007 (c.63), Hea2013 (c.5), Cea2016 (c.65), Pea2017 (c.5), Cea2019 (c.65).

A supratemporal is lost in former "lepospondyls" (e.g. Carroll & Gaskill, 1978; Pardo et al., 2016; Milner, 2018), which have a particularly reduced temporal series. It is also lost in a small number of other taxa including the synapsid *Procynosuchus* (Kemp, 1979) and *Belebey* (Reisz et al., 2007).

Unambiguous: *Acherontiscus caledoniae* (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0), *Belebey vegrandis* (1 -> 0).

125. Supratemporal exposure on occiput: absent, supratemporal restricted entirely to skull table (0); present (1).

A2001 (c.3), Hea2013 (c.6), Pea2017 (c.6).

The supratemporal makes at least a partial contribution to the occiput in many crown amniotes (e.g. Gow, 1972; Gow, 1974; Bolt & Scott, 1995; Reisz & Fröbisch, 2014), captorhinids, *Hylonomus* (Carroll, 1964) and *Paleothyris* (Carroll, 1969).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (1 -> 0), Caseidae (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0). DELTRAN: *Erpetonyx arsenaultorum* (1 -> 0).

126. Supratemporal length relative to width: length is less than three times longer than wide (0); more than three times longer than wide, supratemporal is narrow and strap-like (1).

RC2007 (c.65), ML2019 (c.51), Cea2019 (c.221)

The derived condition of this character is based on metric cut off points observed in the strap-like supratemporal of aïstopods (Anderson, 2002; Pardo et al., 2017). A similar, elongate supratemporal is present in *Westlothiana*, aistopods (Pardo et al. 2017), the seymouriamorphs *Discosauriscus* (Klembara, 1997), the diadectamorph *Orobates* (Berman et al., 2004),

protorothyridids (Carroll, 1964; 1969), *Petrolacosaurus* (Reisz, 1977) and a small number of synapsids (e.g. Romer et al., 1940; Bolt & Scott, 1995; Laurin, 1993)

Unambiguous: Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), *Orobates pabsti* (0 -> 1), *Discosauriscus austriacus* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + Microsauria (0 -> 1), Adelospondyli (1 -> 0), *Araeoscelis gracilis* (1 -> 0), Reptilia (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), Diadectamorpha (1 -> 0). DELTRAN: Aïstopoda (0 -> 1), *Westlothiana lizziae* (0 -> 1), Synapsida (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Euconcordia cunninghami* (0 -> 1).

127. Supratemporal, forms posterodorsal concavity contributing to surface of skull embayment: absent (0), present (1).

Modified from Pea2017 (c37-39).

128. Separately ossified tabular: absent (0); present (1).

LR1997 (c.18), Lea1998 (c.18), A2001 (c.42), Rea2003 (c.67), RC2007 (c.67), ML2019 (c.53), Hea2013 (c.59), Pea2017 (c.53).

Unambiguous: *Adelogyrinus simorhynchus* (1 -> 0), *Phlegethontia linearis* (1 -> 0), Captorhinidae (1 -> 0), *Discosauriscus austriacus* (1 -> 0).

129. Tabular, morphology: broad sub-rectangular sheet located dorsal to the fenestra (0); small and wedge-shaped, located dorsal to the post-temporal fenestra (1); long and narrow, displaced laterally, located dorsolateral to post-temporal fenestra (2); large L-shaped bone enclosing post-temporal fenestra dorsally and laterally (3); tabular absent (inapplicable).

FB2020 (c104). Modified from DR1997 (c.55), SH1998 (c.54), RD2003 (c46), Mea2006 (c.29), Rea2009 (c.51), Bea1995 (c.55), B2012 (c.86), SSS2015 (c.55), Sea2018 (c.64, c.65).

Within amniotes, edaphosaurids (Modesto, 1995) and sphenacodontids (Romer et al., 1940) both possess a tabular that participates significantly in the margin of the posttemporal fenestra.

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), Synapsida (1 -> 0), Varanopidae (0 -> 2), Edaphosauridae + Sphenacodontia (0to3), *Araeoscelis gracilis* (1 -> 2), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 2).

130. Tabular horns: absent (0); present (1).

LR1997 (c.20), Lea1998 (c.20), Rea2003 (c.72), RC2007 (c.68), A2001 (c.43), Bea2000 (c.5), Hea2013 (c61), Pea2017 (c55), Cea2016 (c67), Cea2019 (c67).

A tabular horn is defined here as a posterior extension of the tabular beyond the occiput and the rest of the posterior margin of the skull. Small tabular horns, consisting of short and narrow extensions, are sporadically present across a variety of stem tetrapods, including *Baphetes* (Beaumont, 1977), *Westlothiana*, and anthracosaurs (Panchen, 1977; Holmes, 1989). A very enlarged posterior extension of the tabular, resulting in a skull that is enlarged posteriorly and has a boomerang shape, is distinctly present in diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018), but this is distinguished from other tabular horns in the following character (ch.118).

Unambiguous: *Adelogyrinus simorhynchus* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), Temnospondyli (1 -> 0), *Gerobatrachus hottoni* (0 -> 1), *Greererpeton burkemorani* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Scincosaurus crassus* (1 -> 0), *Gephyrostegus bohemicus* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Brachydectes newberryi* (0 -> 1), Diplocaulidae (0 -> 1), Seymouriamorpha (1 -> 0).

131. Squamosal forms base of tabular horn: absent (0); present (1).

A2001 (c.45), Hea2013 (c.63), Pea2017 (c.53).

As mentioned in ch.116, the tabular horn of diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018) is larger than most other taxa, and changes the overall shape of the skull to resemble a boomerang. As such, the squamosal forms a considerable ventral contribution to the tabular horn.

ACCTRAN: Nectridea (0 -> 1). DELTRAN: Diplocaulidae (0 -> 1).

132. Elements contributing to posterolateral corner of skull table: tabular (0); supratemporal and tabular (1); parietal and supratemporal (2); large supratemporal (3).

Modified from Bea2000 (c.7).

In some taxa scored for state 2 and 3, the tabular has become occipital in its position, such as *Doleserpeton* (Sigurdsen & Bolt, 2010) and *Haptodus* (Laurin, 1993). In captorhinids the tabular is a tiny element (*Captorhinus*; Fox & Bowman, 1966) or lost completely (*Euconcordia*; Reisz et al., 2016), so while it may be situated at the posterolateral corner of the skull, it doesn't contribute significantly. In former "parareptiles" (Gow, 1972; Reisz et al., 2007; Modesto et al., 2015), the supratemporal is expanded and covers the entire posterolateral corner of the skull.

Unambiguous: *Oestocephalus sp.* (0 -> 1), *Haptodus garnettensis* (1 -> 2), *Youngina capensis* (3to2), Captorhinidae (1 -> 2), *Doleserpeton annectens* (0 -> 2). ACCTRAN: Amniota +

Diadectamorpha + Microsauria (0 -> 1), Neoreptilia (1to3). DELTRAN: *Westlothiana lizziae* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Neoreptilia (1to3).

133. Separately ossified postparietals: absent (0); present (1).

Rea2003 (c.47), RC2007 (c.46). Modified from a division of LR1997 (c.22), Lea1998 (c.22), A2001 (c.37), ML2019 (c.39), Cea2019 (c.256), Hea2013 (c.53), Pea2017 (c.47).

Absence of postparietals occurs in a small number of former "lepospondyls", namely the nectridean *Scincosaurus* (Milner & Ruta, 2009) and the aïstopod *Phlegethontia* (Anderson, 2002).

Unambiguous: *Scincosaurus crassus* (1 -> 0), *Phlegethontia linearis* (1 -> 0).

134. Postparietals paired: absent, postparietals are fused into single median element (0); present (1); postparietals absent (inapplicable).

Rea2003 (c.48), RC2007 (c.47). Modified from a division of LR1997 (c.22), Lea1998 (c.22), A2001 (c.37), ML2019 (c.39), Cea2019 (c.256), Hea2013 (c.53), Pea2017 (c.47).

A single, central postparietal is observed in some synapsids including edaphosaurids (Modesto, 1995) and sphenacodontids (Romer et al., 1940), and *Varanosaurus* (Campione & Reisz, 2010). The condition is also observed in *Diadectes* (Berman et al., 1998) and some microsaurs (Carroll & Gaskill, 1978). It has been referred to previously as the interparietal (e.g. Romer et al, 1940).

Unambiguous: *Pantylus cordatus* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Diadectes abistus* (1 -> 0). ACCTRAN: .Synapsida (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), *Procynosuchus delaharpae* (0 -> 1), Seymouriamorpha (1 -> 0), *Ariekanerpeton sigalovi* (0 -> 1). DELTRAN: *Varanops brevirostris* (1 -> 0), *Dimetrodon sp.* (1 -> 0), *Edaphosaurus boanerges* (1 -> 0), *Discosauriscus austriacus* (1 -> 0), *Seymouria sanjuanensis* (1 -> 0).

135. Postparietal size: each postparietal less than 75% of the area of each parietal (0); each postparietal more than 75% of the area of each parietal (1).

A2001 (c.39), Hea2013 (c.55), Pea2017 (c.49).

The choice of 75% of of the area of the parietals as a distinction between states 0 and 1 for this character is based on the choice of 75% in previous analyses. Enlarged postparietals are common within former "lepospondyls" (e.g. Douthitt, 1917; Beerbower, 1963; Carroll & Gaskill, 1978; Pardo et al., 2017; Gee et al., 2021), as well as some stem tetrapods such as *Whatcheeria* (Rawson et al., 2021) and *Greererpeton* (Smithson, 1981).

Unambiguous: *Euryodus sp.* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), *Caerorachis bairdi* (0 -> 1), *Greererpeton burkemorani* (0 -> 1), *Whatcheeria deltae* (0 -> 1). ACCTRAN: *Adelogyrinus simorhynchus* (1 -> 0), *Keraterpeton galvani* (1 -> 0), *Oestocephalus sp.* (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (0 -> 1), *Brachydectes newberryi* (0 -> 1), *Diplocaulus sp. + Diploceraspis sp.* (0 -> 1), *Lethiscus stocki* (0 -> 1).

136. Postparietal posteroventrally sloping occipital exposure: absent, postparietals restricted to skull table (0); present (1).

Rea2003 (c.53), RC2007 (c.52), ML2019 (c.42).

In lysorophians (Pardo et al., 2016), most microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2021) and many crownward stem and crown amniotes (e.g. Carroll, 1969; Gow, 1974; Modesto, 1995; Reisz et al., 2009; Modesto et al., 2015), the surface of the postparietals bends abruptly posteroventrally, exhibiting a slope that continues onto the occipital surface of the skull. In some cases, the postparietals are found entirely, or almost entirely, on the occipital surface and do not even have a dorsal contribution, therefore these postparietals lack a bend but can still be scored as state 1. *Petrolacosaurus*, for example, shows this condition (Reisz, 1977).

Unambiguous: *Hylonomus lyelli* (1 -> 0), *Ariekanerpeton sigalovi* (0 -> 1), *Doleserpeton annectens* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + Microsauria (0 -> 1), *Brachydectes newberryi* (0 -> 1), *Oestocephalus* (0 -> 1), *Westlothiana lizziae* (1 -> 0), *Captorhinus aguti + Opisthodontosaurus carrolli* (1 -> 0). DELTRAN: Adelospondyli (1 -> 0), Diplocaulidae (1 -> 0), *Lethiscus stocki* (1 -> 0), *Hylonomus lyelli + Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), *Captorhinus aguti* (1 -> 0).

137. Postparietal - tabular contact: absent, tabular restricted to posterior position contacted only by supratemporal (0); present (1). Inapplicable in taxa lacking a supratemporal.

Novel

In *Diadectes* (Berman et al, 1998) the tabular is extremely reduced, and is only attached to the supratemporal. In *Hyloplesion*, the parietal and squamosal contact each other posterior to the tabular (Carroll & Gaskill, 1978).

Unambiguous: *Hyloplesion longicostatum* (1 -> 0), *Diadectes abistus* (1 -> 0).

138. Insertion of epaxial musculature on occiput: deep within temporal fossae(0), in broad, shallow fossae along occipital surface of postparietals (1)

Modified from Pea2017 (c235).

Unambiguous: Recumbirostra more derived than *Pantylus* (0 to 1).

139. Ossification within synotic tectum : absent or synotic tectum massively coossified with otic capsules (0), present and paired (1), midline supraoccipital present (2). (ordered).

Modified from J2025a (c217).

Unambiguous: Protorothyridae + Captorhinidae + Amniota (1 to 2), Recumbirostra excluding *Pantylus* (0 to 1).

140. Synotic tectum, endolymphatic fossa on ventral surface: absent (0), present (1).

Modified from J2025a (c273).

141. Supraoccipital, lateral expansion providing dorsal margin of posttemporal fenestra: absent (0); present (1); posttemporal fenestra absent (inapplicable).

FB2020 (c107). Modified from BE1983 (c.15), HR1986 (C), L1993 (c.43), B2012 (c.92)

The supraoccipital makes a contribution to the margin of the posttemporal fenestra in varanopids (Langston & Reisz, 1981; Campione & Reisz, 2010), other synapsids including edaphosaurids (Reisz & Berman, 1986; Modesto, 1995) and sphenacodontids (Romer et al., 1940; Laurin, 1993), and the araeoscelidian *Araeoscelis* (Reisz et al, 1984).

Unambiguous: *Procynosuchus delaharpeae* (1 -> 0). ACCTRAN: .Synapsida (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0). DELTRAN: Varanopidae (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1).

142. Exoccipital - postparietal contact: absent (0); present (1).

Jenkins et al. (2025, c. 387).

This, and all subsequent characters concerning contacts in the skull, are novel and were created from scratch. They will, inevitably, resemble or overlap with previous characters concerning contacts. However, given the potential redundancy with different bone contact characters, all such characters in this paper are not directly based on any other characters. In nearly all total-group amniotes *Diadectes* (Berman et al, 1998), the opisthotics and/or supraoccipital obscure the exoccipitals from the postparietals. In *Westlothiana* and *Doleserpeton* (Sigurdsen & Bolt, 2010) the exoccipitals are obscured in the normal position, but a flange of the postparietals contacts the exoccipitals anyway.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Diploceraspis sp.* (0 -> 1), *Llistrofus pricei* (1 -> 0). DELTRAN: *Microbrachis* pelinaki (0 -> 1), Recumbirostra (0 -> 1).

143. Exoccipital - pterygoid contact: absent (0); present (1).

Novel

The exoccipitals contact the pterygoid ventrally in derived diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963).

Unambiguous: *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1).

144. Dorsal trabeculae morphology: absent or incomplete, no dorsolateral bridge between sphenoid region and nasal capsule (0); dorsal trabeculae provide dorsolateral bridge between sphenoid region and nasal capsule (1).

Pea2017 (c.187).

This is the first of a series of characters from Pardo et al. (2017) that concern the braincase. The braincase was one of the principal focusses of Pardo et al. (2017), and their matrix introduced many completely novel characters concerning the braincase. Here, we use those characters from Pardo et al. (2017) that vary within the taxa included in this analysis.

Unambiguous: *Huskerpeton englehorni* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1). ACCTRAN: Temnospondyli except *Edops craigi* (0 -> 1). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

145. Ossification within columella ethmoidalis: absent (0); present (1).

Pea2017 (c.189).

The columella ethmoidalis is the space between the olfactory nerves, in the anterior braincase. There may be a presphenoid ossification which can fill this space. It is absent in most crownward total-group tetrapods as well as several former "lepospondyls" including the aïstopods *Lethiscus* (Pardo et al., 2017) and *Phlegethontia* (Anderson, 2002). This ossification is present in only the most early-diverging taxa in the matrix such as *Acanthostega* and embolomeres (Pardo 2024).

Unambiguous: *Westolothiana* + *Utaherpeton* + Aistopoda + Tetrapoda (0 → 1), *Greererpeton* (0 → 1).

DELTRAN: *Brachydectes newberryi* (0 -> 1), Synapsida (0 -> 1), *Limnoscelis paludis* (0 -> 1).

146. Anterior extent of cultriform process of parasphenoid relative to sphenethmoid ossification: terminates posterior to sphenethmoid anterior margin (0); terminates in line with sphenethmoid anterior margin (1); terminates clearly anterior to sphenethmoid anterior margin (2); sphenethmoid absent or unossified (inapplicable).(ordered).

Pea2017 (c.193).

A short cultriform process that terminates posterior to the sphenethmoid anterior margin is found in some temnospondyls (Sigurdsen & Bolt, 2010; Arbez et al., 2022), in the stem reptile *Petrolacosaurus* (Pardo et al, 2017), and in the synapsid *Casea* (Olson et al, 1968), although *Dimetrodon* (Romer et al, 1940) possesses a more elongate cultriform process.

Unambiguous: *Oestocephalus sp.* (1 -> 2), *Microbrachis pelikani* (1 -> 2), *Pantylus cordatus* (1 -> 2), Synapsida (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (2 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1), Edaphosauridae + Sphenacodontia (0 -> 2), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (1 -> 2), *Anthracosaurus russelli* (1 -> 2). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1), *Dimetrodon sp.* (0 -> 2), *Captorhinus aguti* (1 -> 2), *Archeria crassidisca* (2 -> 1).

147. Parabasisphenoid, cultriform process is v-shaped in cross section: absent (0), present (1).

148. Olfactory bulbs size: narrow (0); endocasts swollen, leaving considerable impressions in lateral and ventral wall of sphenoid region and in ventral surface of frontal (1).

Pea2017 (c.194).

Enlarged olfactory bulbs that leave impressions in the frontals are found in *Doleserpeton* (Sigurdsen & Bolt, 2010), the synapsid *Procynosuchus* (Kemp, 1979), and in the microsaur *Pantylus* (Carroll & Gaskill, 1978) and *Huskerpeton* (Huttenlocker et al., 2013).

Unambiguous: *Procynosuchus delaharpeae* (0 -> 1). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1). DELTRAN: *Huskerpeton englehorni* (0 -> 1), *Pantylus cordatus* (0 -> 1), *Captorhinus aguti* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

149. Sphenethmoid forms interorbital septum: no (0); yes (1); sphenethmoid absent or unossified (inapplicable).

Pea2017 (c.200).

The sphenethmoid does not form an interorbital septum in *Greererpeton* (Smithson, 1981), temnospondyls (Romer & Witter, 1942; Sigurdsen & Bolt, 2010), most former "lepospondyls" (Carroll & Gaskill, 1978; Pardo et al., 2017; Gee et al., 2019), or diadectamorphs (Romer, 1946). The sphenethmoid does, however, form an interorbital septum in many amniotes crownwards of diadectamorphs (e.g. Romer et al., 1940; Reisz, 1977; Laurin, 1993; Modesto, 1995) and the former "lepospondyls" *Phlegethontia* (Anderson, 2002) and *Brachydectes* (Pardo et al., 2016).

Unambiguous: *Anthracosaurus russelli* (0 -> 1). ACCTRAN: Aïstopoda (0 -> 1), *Lethiscus stocki* (1 -> 0), Amniota (0 -> 1). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Phlegethontia linearis* (0 -> 1), Synapsida (0 -> 1).

150. Posterior extent of parasphenoid beneath braincase: floors sphenoid region only (0); floors sphenoid and otic region (1); floor sphenoid, otic and occipital regions (2). (ordered).

Pea2017 (c.200).

The parasphenoid is restricted to an anterior position, flooring only the sphenoid region (state 0), in the stem tetrapod *Whatcheeria* (Rawson et al., 2021) and in the aïstopod *Lethiscus* (Pardo et al., 2017). State 1, in which the parasphenoid floors the otic region but not the occipital region, is observed in a variety of taxa from many clades including the stem tetrapods *Greererpeton* (Smithson, 1981) and *Baphetes* (Beaumont, 1977), the temnospondyls *Dendrerpeton* (Arbez et al., 2022) and *Edops* (Romer & Witter, 1942), anthracosaurs (Panchen, 1977; Holmes, 1989), captorhinomorphs (Fox & Bowman, 1966; Reisz et al., 2016), synapsids (e.g. Romer et al., 1940; Modesto, 1995) and reptiles such as *Youngina* (Gow, 1974), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and some microsaurs such as *Micraroter*, *Microbrachis* (Carroll & Gaskill, 1978) and *Llistrofus* (Gee et al., 2019). A similarly wide selection of taxa possess state 2 in which the parasphenoid floors the occipital region including the aïstopod *Oestocephalus* (Carroll, 1998), the temnospondyl *Doleserpeton* (Sigurdsen & Bolt, 2010), *Petrolacosaurus* (Reisz, 1977), the diadectamorph *Limnoscelis* (Romer, 1946), the seymouriamorph Seymouria (Berman et al., 2000) and the microsaur *Pantylus* (Carroll & Gaskill, 1978).

Unambiguous: *Pantylus cordatus* (1 -> 2). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Nectridea (2 -> 1), *Lethiscus stocki* + *Phlegethontia linearis* (2 -> 0), Araeoscelidia (1 -> 2), Diadectamorpha (1 -> 2), Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 2), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 ->

2). DELTRAN: *Brachydectes newberryi* (1 -> 2), *Lethiscus stocki* (1 -> 0), *Oestocephalus sp.* (1 -> 2), *Petrolacosaurus kansensis* (1 -> 2), *Limnoscelis paludis* (1 -> 2), *Seymouria sanjuanensis* (1 -> 2), *Doleserpeton annectens* (1 -> 2), *Whatcheeria deltae* (1 -> 0).

151. Basal tubera: absent (0); present (1).

Modified from a division of Pea2017 (c.206).

Basal tubera are widely present across the included taxa, including some stem tetrapods (Smithson, 1981), temnospondyls (Romer & Witter, 1942; Sigurdsen & Bolt, 2010), the stem amniote *Silvanerpeton* (Ruta & Clack, 2006), and many synapsids (e.g. Romer et al., 1940; Langston & Reisz, 1981; Modesto, 1995). However, they are generally lacking in certain clades such as microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2021) and reptiles (Gow, 1974; Ford & Benson, 2019). This character and the following character are a division of Pardo et al (2017) c.206 to allow taxa that retain a basal tubera to be scored together, regardless of the elements that contribute to the basal tubera. Please note that these 'basal tubera' may reflect attachment sites for the branchial apparatus as in *Westlothiana* (Pardo et al. 2018).

Unambiguous: *Lethiscus stocki* (0 -> 1), *Silvanerpeton miripedes* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: *Hapsidopareion lepton* (0 -> 1), Synapsida (0 -> 1), Temnospondyli (0 -> 1), *Dendrerpeton helogenes* (1 -> 0). DELTRAN: *Llistrofus pricei* (0 -> 1), .Synapsida (0 -> 1), *Doleserpeton annectens* (0 -> 1), *Edops craigi* (0 -> 1).

152. Elements contributing to basal tubera: contribution of parasphenoid only (0); significant endochondral contribution (1); basal tubera absent (inapplicable).

Modified from a division of Pea2017 (c206).

ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), Varanopidae (0 -> 1). DELTRAN: Tetrapoda (0 -> 1), *Casea broilii* (1 -> 0), *Dimetrodon sp.* (1 -> 0).

153. Pila antotica morphology: pila antotica is a thin broad sheet (0), pila antotica is a robust dorsoventral pillar bracing the skull roof against the palate (1), pila antotica absent (inapplicable).

Pea2017 (c.209).

Some recumbirostrans (Pardo et al., 2016) have a robust pila antotica.

ACCTRAN: Diadectamorpha (0 -> 1). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Limnoscelis paludis* (0 -> 1).

154. Bone flanking the dorsum sellae: absent (0), consurrent with fully ossified lateral skull roof (1), subparallel with sagittal plane ("pleurosphenoid").

Modified from Pea2017 (c214).

Unambiguous: Recumbirostra more derived than *Pantylus* (0 to 1).

155. Bucohypophyseal foramen or duct in parasphenoid: absent (0), present (1).

Unambiguous: Aistopoda (0 to 1). DELTRAN: Tetrapoda (1 to 0).

156. Basicranial fissure: absent (0), present (1).

Modified from Pea2017 (c210), Cea2019 (c82) and Rea2020 (c159).

Unambiguous: Baphetidae (1to 0), Tetrapoda (1 to 0).

157. Otoccipital region, facets for infrapharyngobranchial articulation (whether ossified or unossified): absent (0), present (1).

This study, based on the observations of Pardo et al. (2018).

The infrapharyngobranchial series articulates with the otooccipital region primitively in stem tetrapods (Pardo et al. 2018). The articular facets for the branchial series on the parabasisphenoid have been previously misinterpreted as ‘basal tubera’ for taxa such as *Silvanerpeton* and embolomeres, whereas they are better interpreted as facets for the ossified or unossified hypobranchials as in *Westlothiana* and aistopods (Pardo et al. 2018).

Unambiguous: Tetrapoda (1 to 0).

158. Otoccipital fissure: present (0), absent (1).

Modified from Pea2017 (c214).

Unambiguous: *Westlothiana* + Aistopoda + Tetrapoda (1 to 0).

159. Cranial notochord: unrestricted (0), restricted in chordal region (1), absent in postembryonic individuals (2). (ordered).

Modified from Pea2017 (c214), Cea2019 (c5), Rea2019 c149).

Unambiguous: Tetrapoda (1 to 2).

160. Posterior median ossification 'subiculum infundibulum' of ethmoid trabecullae: absent (0), present (1).

Modified from Pea2017 (c299).

Unambiguous: Nastrondormes (0 → 1).

161. Ossification between optic foramen and pila antotica: ossification complete between optic foramen and pila antotica (0), pila metoptica and associated cartilaginous taeniae unossified (1).

Modified from Pea2017 (c188).

Unambiguous: *Greererpeton* (0 to 1), Tetrapoda (0 to 1), *Micraroter* + Gymnarthridae (1 → 0).

162. Path of profundus branch of trigeminal nerve: enclosed in lateral wall of sphenoid region of braincase and exits separately from maxillomandibular branch via a series of small foramina (0), extramural, exits antotic fissure with other branches of trigeminal (1).

Modified from Pea2017 (c190).

Unambiguous: Tetrapoda (0 to 1).

163. Opisthotic, otic trough: absent (0), present (1).

Modified from Pea2017 (c230).

Unambiguous: Synapsida (0 → 1). ACCTRAN: Diadectomorpha (0 → 1).

164. Opisthotic, crista intervestibularis: absent (0), present (1).

Modified from Pea2017 (c221).

Unambiguous: Total group Amniota (0 → 1).

165. Prootic, contact with counterpart on midline: absent (0), present (1)

Modified from J2026 (c. 312).

Unambiguous: Eupelycosauria (0 to 1).

166. Articulation between the epipterygoid and prootic: absent (0), present (1).

Modified from Pea2017 (c230).

Unambiguous: *Doleserpeton* + Nectrideans (0 to 1).

167. Epipterygoid laterally contributing to basal articulation: no, basal articulation is entirely within the pterygoid and epipterygoid does not contact the basipterygoid process of the parasphenoid, or caps the joint (0); yes (1).

Pea2017 (c.212).

In most taxa included in this analysis, the epipterygoid articulates at least partially laterally with the parasphenoid, as can be observed in the anthracosaur *Archeria* (Holmes, 1989) or the lysorophian lepospondyl *Brachydectes* (Pardo et al., 2016). In parapleurotan reptiles, the epipterygoid does not have a lateral contribution to the basal articulation, which is made up entirely of the parasphenoid and pterygoid. Instead, it sits entirely dorsal to the contact between the parasphenoid and pterygoid, and caps the joint between them. This is particularly clear in *Orovenator* (Ford & Benson, 2019), millerettids (Jenkins et al. 2025a-c) and *Youngina* (Gow, 1974) and separately in the diadectamorph *Limnoscelis* (Romer, 1946).

Unambiguous: Reptilia (1 -> 0), *Limnoscelis paludis* (1 -> 0).

168. Sphenethmoid ossification: unossified (0), ossified (1).

Pea2017 (c.216)

An ossified sphenethmoid is absent in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) but is present across most ingroup taxa, although it is subsequently lost in a small number of disparate taxa including *Oestocephalus* (Anderson, 2002) and *Microbrachis* (Carroll & Gaskill, 1978), and parapleurotan reptiles (Jenkins et al. 2025d).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), *Oestocephalus sp.* (1 -> 0), *Microbrachis pelikani* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0), *Seymouria sanjuanensis* (1 -> 0).

169. Elements contributing to margin of fenestra vestibuli: parasphenoid excluded by neurocranial elements (basisphenoid and basioccipital) (0), parasphenoid contributes to anteroventral margin of fenestra vestibuli (1), parasphenoid floors entire fenestra vestibuli (2), ossification of otic capsule surrounds entire fenestra vestibuli (3). (ordered).

Pea2017 (c.220)

ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 2), Aïstopoda (2 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* (2 -> 3), *Hapsidopareion lepton* (2 -> 0), Edaphosauridae + Sphenacodontia (2 -> 3). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 2), *Lethiscus stocki* (2 -> 0), *Euryodus sp.* (2 -> 3), *Llistrofus pricei* (2 -> 0), *Dimetrodon sp.* (2 -> 3), *Whatcheeria deltae* (1 -> 0).

170. Opisthotic, paraoccipital process attachment: ends freely (0); extends dorsolaterally and contacts skull table or occiput (1), extends lateral and contacts squamosal or quadrate (2) . (ordered).

FB2020 (c.115).

In stem tetrapods (Beaumont, 1977; Smithson, 1981) temnospondyls (e.g. *Doleserpeton*; Sigurdsen & Bolt, 2010), and most stem amniotes (e.g. Panchen, 1977; Berman et al., 2000; Berman et al., 2004), the paraoccipital process contacts the dorsal skull. In captorhinids (Fox & Bowman, 1966; Reisz et al., 2016) and *Paleothyris* (Carroll, 1969), *Petrolacosaurus* (Reisz, 1977), the basal synapsid *Varanosaurus* (Campione & Reisz, 2010) and in some former "parareptiles" (Reisz et al., 2007) the paraoccipital process ends freely and does not contact the dermal skull bones distally, although there is certainly an ontogenetic component here. In *Araeoscelis* (Reisz et al., 1984), *Milleropsis* (Gow, 1972), and *Youngina* (Gow, 1974) and synapsids, the plesiomorphic condition of the paraoccipital process contacting the skull distally is present (e.g. Olson et al., 1968; Modesto, 1995; Reisz et al., 2009).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), .Synapsida (1 -> 0), *Araeoscelis gracilis* (1 -> 0).

171. Opisthotic obscures occipital in lateral view: no, occipital is visible in lateral view (0); yes, occipital is not visible in lateral view (1).

Pea2017 (c.231)

The only included taxon in which the occipital is obscured in lateral view is *Dimetrodon* (Romer et al, 1940; Pardo et al, 2017).

ACCTRAN: Edaphosauridae + Sphenacodontia (0 -> 1). DELTRAN: Sphenacodontidae (0 -> 1).

172. Occipital condyle shape: round, concave (0); round, convex (1); paired (2).

Modified from Hea2013 (c.84, c.85), Pea2017 (c.238).

The wording of this character has been slightly modified from previous studies. Huttenlocker et al. (2013) had two characters, one concerning whether or not the shape of the occipital condyle was concave or convex (c.84) and whether the occipital condyle was single or double (c.85). However, this wording has some redundancy because a paired condyle can be concave. Pardo et al. (2017) had a single character (c.238) with three states, being round, U-shaped, or paired. This wording is unclear because round is vague, and a variety of shapes can be considered round. The new wording here provides greater clarity. A paired condyle specifically, which can be concave in between the posterior projections, is distinguished from a concave condyle in that a paired condyle possesses two posteriorly projecting processes that project beyond the posterior skull margin, with a concavity in between. A concave condyle is considered to be one in which the shape of the condyle is concave, but these projections are lacking. In particular, most microsaurs show a paired condyle (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2021), which articulates with the odontoid process present on the atlas. Nectrideans also possess a paired condyle (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018).

Unambiguous: Aïstopoda (2 -> 0), *Cardiocephalus sp.* (2 -> 0), *Balanerpeton woodi* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), Araeoscelidia (1 -> 2), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), Diadectamorpha (1 -> 0). DELTRAN: Amniota (0 -> 1), *Casea broilii* (1 -> 0), *Petrolacosaurus kansensis* (1 -> 2), *Euconcordia cunninghami* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1).

173. Ossification of the median wall of the otic capsule: completely unossified (0); ossification of opisthotic (1).

Pea2017 (c.251).

The ossification of the otic capsule shows a variety of conditions across the included taxa. For example, in synapsids the opisthotic is well ossified (e.g. Romer et al., 1940; Laurin, 1993; Modesto, 1995), whereas in former "lepospondyls" there is a greater variety of conditions, with states 0 and 1 all represented within microsaurs, for example in *Llistrofus* (Gee et al., 2019) and *Euryodus* (Gee et al., 2021) and *Cardiocephalus* (Carroll & Gaskill, 1978) respectively.

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 2), *Euryodus sp.* (2 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 2), *Microbrachis pelikani* (0 -> 1), Synapsida (2 -> 1), *Gephyrostegus bohemicus* (2 -> 1). DELTRAN: Aïstopoda (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Hylonomus lyelli* + *Paleothyris*

acadiana + Captorhinidae + Amniota + Diadectamorpha (1 -> 2), .Synapsida (2 -> 1), *Seymouria sanjuanensis* (1 -> 2).

174. Semicircular canals separated from utricular region by bone: not separated (0); separated (1).

Pea2017 (c.253).

ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Aïstopoda (0 -> 1), *Pantylus cordatus* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Huskerpeton englehorni* (0 -> 1), *Llistrofus pricei* (0 -> 1), *Archeria crassidisca* (0 -> 1).

175. Elongate, broad posterolateral processes on parasphenoid: absent (0); present (1).

Modified from a division of RC2007 (c.179), ML2019 (c.139).

The posterior margins of the parasphenoid plate are drawn out into wide, elongate processes that project laterally in several taxa. They are best demonstrated in seymouriamorphs such as *Discosauriscus* (Klembara, 1997) and *Ariekanerpeton* (Klembara & Ruta, 2005).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), Seymouriamorpha (0 -> 1), *Balanerpeton woodi* (0 -> 1).

176. Shape of basal plate of parasphenoid: triangular (0); rectangular (1).

RC2007 (c.186), ML2019 (c.145), Hea2013 (c.105), Pea2017 (c.215).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Aïstopoda (0 -> 1), Adelospondyli (1 -> 0), Temnospondyli (0 -> 1). ACCTRAN: Caseasauria (0 -> 1), Seymouriamorpha (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0). DELTRAN: *Eothyris parkeyi* (0 -> 1), *Discosauriscus austriacus* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1).

177. Parasphenoid much wider than long immediately posterior to level of basal articulation: absent (0); present (1).

Rea2003 (c.176), RC2007 (c.185), ML2019 (c.144).

In temnospondyls and *Gerobatrachus*, the parasphenoid plate is extremely wide. The anterior margin of the plate, immediately posterior to the basal articulation, expands rapidly to reach the maximum width of the plate, which is wider than it is long (Romer & Witter, 1942; Milner & Sequeira, 1993; Anderson et al., 2008; Sigurdsen & Bolt, 2010; Arbez et al., 2022).

Unambiguous: Temnospondyli (0 -> 1).

178. Depression in body of parasphenoid: absent (0); single, median depression (1); paired lateral depressions (2).

Rea2003 (c.171), RC2007 (c.180), Cea2016 (c.77), ML2019 (c.140), Cea2019 (c.77).

Most amniotes (e.g. Romer et al., 1940; Gow, 1974; Reisz & Dilkes, 2003; Bolt & Scott, 1995) and stem amniotes (e.g. Fox & Bowman, 1966; Panchen, 1977; Clack & Ruta, 2006) have a single, central depression in the parasphenoid. Temnospondyls lack any depression (e.g. Romer & Witter, 1942; Milner & Sequeira, 1993; Arbez et al., 2022), as do former "lepospondyls" (e.g. Beerbower, 1963; Carroll & Gaskill, 1978; Pardo et al., 2016; 2017), with the exception of *Westlothiana* which retains a single, central depression. The presence of this character in small-bodied early tetrapodomorphs may be overlooked or undescribed.

Unambiguous: *Procynosuchus delaharpeae* (1 -> 2), *Seymouria sanjuanensis* (1 -> 0), *Archeria crassidisca* (1 -> 0). Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 2), Tetrapoda (2 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1). DELTRAN: Temnospondyli (1 -> 0), *Baphetes sp.* (1 -> 2), *Greererpeton burkemorani* (1 -> 2).

179. Parasphenoid cultriform process: tapering along most of length (0); parallel sided for most of length (1).

Rea2003 (c.169), RC2007 (c.176), Cea2016 (c.76), ML2019 (c.136), Cea2019 (c.76).

Generally, the cultriform process is parallel sided, or close to parallel sided, such as in the aïstopod *Lethiscus* (Pardo et al., 2017), the diadectamorph *Orobates* (Berman et al., 2004), or in *Petrolacosaurus* (Reisz, 1977). However, in several taxa the cultriform process tapers to a degree significant enough to consider the shape of the cultriform process as distinctly triangular. Examples include *Ariekanerpeton* (Klembara & Ruta, 2005) or *Silvanerpeton* (Ruta & Clack, 2006).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), *Tuditanus punctulatus* (1 -> 0), *Huskerpeton englehorni* (1 -> 0), *Hapsidopareion lepton* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), Adelospondyli (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (1 -> 0), Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0).

180. Cultriform process of parasphenoid contacting vomers: absent (0); present (1).

Pea2017 (c.202).

This character is related to ch.169, which describes whether or not the pterygoids contact on the midline, as previously described. The distribution of states is related, as those taxa in which the cultriform process of the parasphenoid contacts the vomers also lack a midline contact of the pterygoids, a condition clearly demonstrated, for example, in *Doleserpeton* (Sigurdsen & Bolt, 2010). However, as discussed in ch.169, not all taxa that lack a pterygoid midline contact possess a contact between the cultriform process and vomers, and as such they are retained as separate characters. Temnospondyls (see ch.69) and nectrideans (e.g. Beerbower, 1963; Milner, 2018) have a cultriform process that contacts the vomers.

Unambiguous: Nectridea + Temnospondyli (0 -> 1).

181. Denticle shagreen on parasphenoid: absent (0); present (1).

LR1997 (c.60), Lea1998 (c.58), A2001 (c.79), RC2007 (c.184), Cea2016 (c.101), Cea2019 (c.101), Hea2013 (c.102), Pea2017 (c.281), Cea2016 (c.102), Cea2019 (c.102), Kea2014 (c.55).

Denticles are present on the parasphenoid, typically at the posterior end of the cultriform process and the anterior end of the parasphenoid plate, in most stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005). They are also present widely across crown tetrapods in many disparate clades, including stem tetrapods such as *Westlothiana*, temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022) and *Gerobatrachus* (Anderson et al., 2008), *Silvanerpeton* (Ruta & Clack, 2006), *Solenodonsaurus* (Danto et al., 2012), most seymouriamorphs (Klembara, 1997; Berman et al., 2000), some microsaurs (Carroll & Gaskill, 1978; Gee et al., 2019), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016), protorothyridids (Carroll, 1964; 1969), *Petrolacosaurus* (Reisz, 1977), *Orovenator* (Ford & Benson, 2019) and *Casea* (Olson et al., 1968).

Unambiguous: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Petrolacosaurus kansensis* (0 -> 1), *Orovenator mayorum* (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0), *Gephyrostegus bohemicus* (1 -> 0), Embolomeri (1 -> 0), *Whatcheeria deltae* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), *Hyloplesion longicostatum* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), Caseidae (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 1). DELTRAN: *Tuditanus punctulatus* (1 -> 0), Amniota (1 -> 0), *Casea* broili (0 -> 1), Diadectamorpha (1 -> 0).

182. Separately ossified vomer: present (0) absent (1).

This study.

Unambiguous: *Oestocephalus* + *Phlegethontia* (0 to 1).

183. Vomer anteroposterior length relative to transverse width: shorter than or equal to twice as long as wide (0); longer than twice as long as wide (1).

Rea2003 (c.117), Cea2016 (c.91), Pea2017 (c.275), Cea2019 (c.91), ML2019 (c.102). Modified from a division of RC2007 (c.122, c.132).

In stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) the vomers are relatively anteroposteriorly short and transversely wide. This is particularly pronounced in temnospondyls, the vomers are particularly, and distinctly transversely wide (Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022). In *Westlothiana*, *Whatcheeria*, most anthracosaurs (Panchen, 1977) and *Silvanerpeton* (Ruta & Clack, 2006), seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016), synapsids (e.g. Bolt & Scott, 1995; Modesto, 1995), former "parareptiles" (Gow, 1972; Reisz et al., 2007; Modesto et al., 2015) and *Youngina* (Gow, 1974) the vomer is elongated. Nectrideans, like temnospondyls, (Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) show anteroposteriorly shorter vomers, and are thus scored as state 0.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Nectridea (1 -> 0), *Hylonomus lyelli* (1 -> 0). ACCTRAN: *Diadectes abistus* + *Orobates pabsti* (1 -> 0). DELTRAN: *Diadectes abistus* (1 -> 0).

184. Vomer separation by pterygoids relative to length: not separated at all by pterygoids (0); separated for less than half of anteroposterior length of vomers (1); separated for more than half of anteroposterior length of vomers (2). (ordered).

Cea2019 (c.88), Cea2016 (c.88), Pea2017 (c.274).

Where the pterygoids partially overlap with the vomers, and contact them medially so that they interrupt the midline suture of the vomers, then state 1 or 2 is present. There is a great variety of the extent of contact between the vomers and the pterygoids in ingroup taxa. For example, state 1, in which the overlap is less than half of the anteroposterior length of the vomers, is present in the stem tetrapod *Greererpeton* (Smithson, 1981), the possible anthracosaur *Silvanerpeton* (Ruta & Clack, 2006), and in *Youngina* (Gow, 1974). A degree of overlap reaching more than half the anteroposterior length of the vomers is present in seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005) and some microsaurs (Carroll & Gaskill, 1978).

Unambiguous: *Pantylus cordatus* (2 -> 1), *Youngina capensis* (0 -> 1), *Orovenator mayorum* (0 -> 1), *Euconcordia cunninghami* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 0),

Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (0 -> 1), Araeoscelidia (0 -> 1), Seymouriamorpha (0 -> 2), *Silvanerpeton miripedes* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 2), *Caerorachis bairdi* (0 -> 1), *Edops craigi* (0 -> 1). DELTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), *Casea* broili (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), Seymouriamorpha (1 -> 2), *Gephyrostegus bohemicus* (1 -> 0), *Anthracosaurus russelli* (1 -> 0), *Chroniosaurus dongusensis* (1 -> 2), Temnospondyli except *Edops craigi* (1 -> 0), *Baphetes sp.* (1 -> 0).

185. Vomer, asymmetric bifurcated anterior processes: absent (0); present, vomer terminates anteriorly in short lateral and elongate medial projections (1).

FB2020 (c134).

A division of the anterior margin of the vomer into two distinct processes, as described in Ford & Benson (2020), is present in *Paleothyris* (Carroll, 1969), the araeoscelid *Petrolacosaurus* (Reisz, 1977), and *Archaeovenator* (Reisz & Dilkes, 2003) and *Orovenator* (Ford & Benson, 2019), identified by Ford & Benson (2020) as varanopids and recovered here as basal stem reptiles. It is also present in the parareptile *Erpetonyx* (Modesto et al., 2015), as well as the diadectamorph *Limnoscelis* (Romer, 1946) and the microsaur *Euryodus* (Gee et al., 2021). It is absent, however, in *Youngina* (Gow, 1974), millerettids (Gow, 1972) and synapsids (e.g. Romer et al., 1940; Laurin, 1993; Bolt & Scott, 1995)

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Synapsida (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), Neoreptilia (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1), Captorhinidae (1 -> 0). DELTRAN: *Euryodus sp.* (0 -> 1), *Youngina capensis* (1 -> 0), *Milleropsis pricei* (1 -> 0), *Captorhinus aguti* (1 -> 0).

186. Anterior palatal fenestra: absent (0); present, single (1); present, double (2). (ordered).

Cea2016 (c.156), Cea2019 (c.156), Pea2017 (c.340).

A vacuity in the anterior palate, in addition to the choanae, is present in stem tetrapods such as *Whatcheeria* (Rawson et al., 2022), *Greererpeton* (Smithson, 1981) aïstopods (Anderson, 2002; Pardo et al., 2017), and *Westlothiana*.

Unambiguous: *Greererpeton burkemorani* (0 -> 2). ACCTRAN: Aïstopoda (0 -> 1). DELTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1).

187. Choana transversely wider in anterior half than posterior half: no, anterior half is equal in transverse width or narrower than posterior half (0); wider in anterior half (1).

Rea2003 (c.157), RC2007 (c.164), ML2019 (c.130).

The choana is transversely wider in the anterior half, giving a distinct teardrop shape, in derived temnospondyls (Sigurdsen & Bolt, 2010; Arbez et al., 2022) and *Gerobatrachus* (Anderson et al., 2008).

Unambiguous: *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1).

188. Fangs on vomer: absent (0); present (1).

LR1997 (c.42), Lea1998 (c.40), Rea2003 (c.118), RC2007 (c.183), Cea2016 (c.106), ML2019 (c.103), Cea2019 (c.106), Pea2017 (c.290).

Fangs on the vomer are present in stem tetrapods including *Westlothiana* (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021). They are absent, however, in a variety of taxa from clades across crown tetrapods, including *Lethiscus* (Pardo et al., 2017), nectrideans (Douthitt, 1917, Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) , derived temnospondyls such as *Doleserpeton* (Sigurdsen & Bolt, 2010) and *Gerobatrachus* (Anderson et al., 2008), synapsids (e.g. Laurin, 1993; Bolt & Scott, 1995; Brocklehurst et al., 2016), protorothyridids (Carroll, 1964; 1969), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016), diadectamorphs (Romer, 1946; Berman et al., 1998; 2004), and microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2019; 2021).

Unambiguous: Embolomeri + *Chroniosaurus dongusensis* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Westlothiana lizziae* (0 -> 1), Neoreptilia (0 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0). DELTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), *Youngina capensis* (0 -> 1), *Milleretta* (0 -> 1).

189. Denticle shagreen on vomer: absent (0); present (1).

LR1997 (c.43), Lea1998 (c.41), A2001 (c.77), Rea2003 (c.119), RC2007 (c.124, c.130), Cea2016 (c.110, c.111), ML2019 (c.104), Cea2019 (c.110, c.111), Hea2013 (c.100), Pea2017 (c.294).

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), Aïstopoda (1 -> 0), *Cardiocephalus sp.* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Vaughnitis smithae* (1 -> 0), Sphenacodontidae (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), Neoreptilia (1 -> 0), *Captorhinus aguti* (1 -> 0), *Paleothyris acadiana* (1 -> 0), *Diadectes abistus* + *Orobates pabsti* (1 -> 0), *Pederpes finneyae* (0 -> 1). ACCTRAN: Embolomeri (1 -> 0). DELTRAN: *Anthracosaurus russelli* (1 -> 0).

190. Row of at least three teeth on vomer, comparable in size to marginal teeth: absent (0); present (1).

ML2019 (c.107). Modified from LR1997 (c.40), Lea1998 (c.38), Cea2016 (c.108), Cea2019 (c.109), Pea2017 (c.293). Modified from a division of Kea2014 (c.60).

A toothrow on the vomer is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) but is absent in the stem tetrapods *Greererpeton* (Smithson, 1981) and *Baphetes* (Beaumont, 1977). A toothrow is absent in most crown tetrapods included in this *Doleserpeton* (Sigurdsen & Bolt, 2010), the synapsids *Vaughnitis* (Brocklehurst et al., 2016) and *Varanosaurus* (Bolt & Scott, 1995), *Youngina* (Gow, 1974), *Orobates* (Berman et al., 2004), diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018), *Brachydectes* (Pardo et al., 2016) and a small number of microsaurs, namely *Cardiocephalus* (Carroll & Gaskill, 1978), *Euryodus* (Gee et al., 2021) and *Huskerpeton* (Huttenlocker et al., 2013).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0). Aïstopoda (0 -> 1), *Scincosaurus crassus* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), *Vaughnitis smithae* (0 -> 1), *Varanosaurus acutirostris* (0 -> 1), *Youngina capensis* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), *Doleserpeton annectens* (0 -> 1), *Edops craigi* (0 -> 1).

191. Vomerine fangs noticeably smaller than other palatal fangs: no, fangs are equal in size to other palatal fangs (0); yes (1), vomerine fangs absent (inapplicable).

Cea2016 (c.107), Cea2019 (c.107), Pea2017 (c.291).

The vomerine fangs are substantially smaller than the other palatal fangs in the outgroup (Clack & Finney, 2005; Rawson et al., 2021), and the stem tetrapod *Greererpeton* (Smithson, 1981). The condition is also observed in the temnospondyls *Edops* (Romer & Witter, 1942) and *Dendrerpeton* (Arbez et al., 2022), as well as the *Gephyrostegus* (Klembara et al, 2014).

Unambiguous: *Gephyrostegus bohemicus* (0 -> 1), *Balanerpeton woodi* (1 -> 0), *Baphetes sp.* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0).

192. Separately ossified palatine: absent (0); present (1).

LR1997 (c.44), Lea1998 (c.42), RC2007 (c.139), ML2019 (c.114)

A separately ossified palatine is lost in the aïstopod *Phlegethontia* (Anderson, 2002).

Unambiguous: *Phlegethontia linearis* (1 -> 0).

193. Ectopterygoid - palatine exposure: narrow, approximately confined to tooth row (0); broad medial exposure additional to tooth row (1).

Cea2016 (c.73), Cea2019 (c.73), Pea2017 (c.258).

A small number of disparate taxa show a reduction in the width of the ectopterygoid and palatine. In these taxa, the palatine and ectopterygoid are only approximately as wide as the row of teeth on these elements. This condition is observed in Nectrideans (Milner, 2018; Clack et al., 2019) and derived temnospondyls and *Gerobatrachus* (Anderson et al., 2008; Sigurdsen & Bolt, 2010), as well as in *Whatcheeria* (Rawson et al., 2021).

Unambiguous: *Acherontiscus caledoniae* (1 -> 0), *Keraterpeton galvani* (1 -> 0), *Micraroter erythrogeois* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0), *Whatcheeria deltae* (1 -> 0).

194. Ectopterygoid - palatine width: narrower than maxilla (0); wider than maxilla (1).

Hea2013 (c.122, Pea2017 (c.86).

This character is somewhat related to the previous character, and as such some taxa score the narrower condition for both, such as *Keraterpeton* (Milner, 2018) and dissorophoid temnospondyls and *Gerobatrachus* (Anderson et al., 2008; Sigurdsen & Bolt, 2010). However, several taxa demonstrate a palatine that is narrower than the maxilla but not so narrow and width as to be confined to the width of the toothrow, such as *Brachydectes* (Pardo et al., 2016) and as such the characters are scored separately.

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Keraterpeton galvani* (1 -> 0). ACCTRAN: Neoreptilia (1 -> 0), *Youngina capensis* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Belebey vegrandis* (1 -> 0), *Milleropsis pricei* (1 -> 0), *Diadectes abistus* (1 -> 0), *Gerobatrachus hottoni* (1 -> 0).

195. Fangs on palatine: absent (0); present (1).

LR1997 (c.46), Lea1998 (c.44), Rea2003 (c.127), RC2007 (c.133), Cea2016 (c.98), ML2019 (c.110), Cea2019 (c.98).

Fangs on the palatine follow a similar distribution to fangs on the ectopterygoid (ch.186), and are present in all taxa that possess ectopterygoid fangs. However, they are present in some taxa that lack ectopterygoid fangs, such as *Lethiscus* (Pardo et al., 2017) and seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005).

Unambiguous: *Chroniosaurus dongusensis* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + Microsauria (1 -> 0), *Lethiscus stocki* (0 -> 1).

196. Denticle shagreen on palatine: absent (0); present (1).

LR1997 (c.47), Lea1998 (c.45), A2001 (c.78), Rea2003 (c.128), RC2007 (c.134), Cea2016 (c.100), ML2019 (c.111), Cea2019 (c.100), Hea2013 (c.101)

A denticle shagreen on the palatine occurs in most of the same taxa as a denticle shagreen on the ectopterygoid (ch.187). However, there are a small number of taxa in which this is not the case. *Acherontiscus* is considered to have denticles on the palatine but a tooth row on the ectopterygoid, although our observation of the scan data of this taxon shows that enlarged teeth and smaller denticles are present (Clack et al., 2019). In *Archaeovenator*, the denticles extend across the pterygoid and palatine but not the ectopterygoid (Reisz et al., 1984), and palatal denticles are restricted only to the palatine in *Scincosaurus* (Milner & Ruta, 2009). Conversely, *Llistrofus* possesses a small patch of denticles restricted only to the ectopterygoid and thus lacks denticles on the palatine (Gee et al., 2019).

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), Aïstopoda (1 -> 0), *Scincosaurus crassus* (0 -> 1), *Vaughnitis smithae* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), Neoreptilia (1 -> 0), *Diadectes abistus* + *Orobates pabsti* (1 -> 0), *Doleserpeton annectens* (1 -> 0), *Pederpes finneyae* (0 -> 1). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Euryodus sp.* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), Embolomeri (1 -> 0). DELTRAN: *Cardiocephalus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Anthracosaurus russelli* (1 -> 0).

197. Row of at least three teeth on palatine, comparable in size to marginal teeth: absent (0); present (1).

Rea2003 (c.130), RC2007 (c.135), Cea2016 (c.99), ML2019 (c.112), Cea2019 (c.99), Pea2017 (c.86). Modified from a division of LR1997 (c.39), Lea1998 (c.37).

A row of teeth on the palatine is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and the stem tetrapod *Greererpeton* (Smithson, 1981) but is absent in most taxa crownwards of this. A toothrow is nonetheless present in a small number of taxa, particularly within diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018) and derived temnospondyls such as *Doleserpeton*.

Unambiguous: Tetrapoda + *Baphetes sp.* (1 -> 0), Diplocaulidae (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

198. Size of palatal teeth relative to marginals: palatal teeth are smaller than marginals (0); palatal teeth are equal in size to marginals (1); palatal teeth are larger than marginals (2). (ordered).

A2001 (c.80), Hea2013 (c.103), Pea2017 (c.81).

In most included taxa, even those with palatal fangs or toothrows, the palatal teeth are either roughly equivalent or smaller than the marginal teeth. However, in the stem tetrapods *Greererpeton* (Smithson, 1981), *Baphetes* (Beaumont, 1977), *Westlothiana*, and in temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010), the palatal fangs are clearly larger than the marginal teeth.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 0), *Asaphestera intermedia* (0 -> 2), *Westlothiana lizziae* (0 -> 1), Seymouriamorpha (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 2), Diplocaulidae (0 -> 1), *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1). DELTRAN: *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1), *Lethiscus stocki* (0 -> 1), *Whatcheeria deltae* (2 -> 0).

199. Transverse flange of pterygoid: absent (0); present (1).

LR1997 (c.52), Lea1998 (c.49), Rea2003 (c.141), RC2007 (c.147), ML2019 (c.119).

A transverse flange of the pterygoid is found in some embolomeres, some temnospondyls (e.g., *Acheloma*, Gee et al. 2019, stem amniotes (Carroll, 1964; Fox & Bowman, 1966; Carroll, 1969) and early crown amniotes (e.g. Reisz & Dilkes, 2003; Campione & Reisz, 2010; Reisz & Fröbisch, 2014), although it is not present in microsaurs (e.g. Carroll & Gaskill, 1978; Pardo et al., 2017; Milner, 2018; Gee et al., 2019), bolosaurids (Reisz et al. 2007), and most stem tetrapods including *Westlothiana*.

Unambiguous: *Chroniosaurus dongusensis* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1). DELTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1).

200. Pterygoids contact each other anteriorly along midline: do not contact (0); contact each other (1).

A2001 (c.90), Cea2016 (c.83), Cea2019 (c.83), Hea2013 (c.116).

In many ingroup taxa, the pterygoids meet along the midline, from the stem tetrapods *Greererpeton* (Smithson, 1981) and *Baphetes* (Beaumont, 1977) and anthracosaurs (Panchen, 1977) such as *Silvanerpeton* (Ruta & Clack, 2005), to stem amniotes such as

seymouriamorphs (e.g. Klembara & Ruta, 2005), diadectamorphs (e.g. Berman et al., 2004), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016) and many crown amniotes (e.g. Bolt & Scott, 1995, Ford & Benson, 2019). In temnospondyls more derived than *Edops*, including *Gerobatrachus*, the cultriform process contacts the vomers and prevents contact between the pterygoids (Milner & Sequeira, 1993; Anderson et al., 2008; Sigurdsen & Bolt, 2010; Arbez et al., 2022). In some former "lepospondyls", such as *Lethiscus* (Pardo et al, 2017) the pterygoids are widely separated, despite the cultriform process not reaching forward sufficiently to contact the vomers.

Unambiguous: *Llistrofus pricei* (1 -> 0), *Westlothiana* (1 -> 0), Temnospondyli except *Edops craigi* (1 -> 0). ACCTRAN: Adelospondyli (0 -> 1), *Oestocephalus sp.* (0 -> 1). DELTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), *Hyloplesion longicostatum* (1 -> 0).

201. Pterygoid quadrate ramus orientation: mostly caudally (0); or mostly laterally in ventral aspect (1).

Rea2003 (c.143), RC2007 (c.148), ML2019 (c.120).

In nectrideans, the quadrate ramus of the pterygoid has become rotated forwards so that they face more lateral than caudal, with the dominant direction more than 45 degrees from the midline of the skull (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018). A similar condition is observed in the aïstopod *Phlegethontia* (Anderson, 2002).

Unambiguous: Nectridea (0 -> 1), *Phlegethontia linearis* (0 -> 1).

202. Quadrate ramus of pterygoid breadth: shorter than or equal to twice as long as maximum width (0); more than twice as long as maximum width (1).

Rea2003 (c.149), RC2007 (c.154).

In nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), lysorophians (Pardo et al., 2016), and a small number of other, disparate taxa from across the phylogeny, including *Phlegethontia* (Anderson, 2002) and *Silvanerpeton* (Clack & Ruta, 2006), the quadrate ramus of the pterygoid is more robust than is typical for most taxa, and has become at least half as broad as it is long. In these taxa it is less clearly separated from the rest of the pterygoid.

Unambiguous: *Phlegethontia linearis* (1 -> 0), *Orobates pabsti* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0).

203. Pterygoid quadrate ramus margin in adductor fossa: concave (0), with some convex component (1).

Cea2016 (c.85), Cea2019 (c.85), Pea2017 (c.273).

Unambiguous: Tetrapoda (0 -> 1), *Huskerpeton englehorni* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1), *Captorhinus aguti* (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0), *Gephyrostegus bohemicus* (1 -> 0), *Doleserpeton annectens* (1 -> 0).

204. Pterygoid, quadrate ramus, median shelf (='posteromedian flange'; 'tympanic flange';'arcuate flange'): absent (0); present (1).

FB2020 (c.146). Modified from B2012 (c.120), BE1983 (c.14), Rea1992 (c.37), L1993 (c.40), Bea1995 (c.46), Fea2011 (c.102), MR2014 (c.65), Mea2015 (c.65).

An arcuate flange is present in several synapsids including caseasaurs (Olson et al., 1968; Reisz et al., 2009) and varanopids including *Archaeovenator* (Bolt & Scott, 1995; Langston & Reisz, 1981; Reisz & Dilkes, 2003) and is present, but reduced to a low keel, in edaphosaurids (Modesto, 1995) or sphenacodontids (Laurin, 1993, Romer et al., 1940). It is also present in total-group *Orovenator* (Ford & Benson, 2019) and in the former "parareptiles" *Belebey* (Reisz et al., 2007), *Milleretta* (Gow, 1972), and *Youngina* (Gow, 1974). It is also present in a small number of stem amniote taxa including diadectamorphs (Romer, 1946; Berman et al., 1998; 2004) and possibly *Chroniosaurus* (Clack & Klembara, 2009).

Unambiguous: Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), *Araeoscelis gracilis* (0 -> 1), Neoreptilia (0 -> 1), *Youngina capensis* (1 -> 0), *Euconcordia cunninghami* (0 -> 1), Diadectamorpha (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1).

205. Pterygoid, quadrate ramus, descending flange: absent (0), present (1).

Modified from Cea2019 (c86).

The quadrate ramus of embolomeres (e.g., *Archeria*, Holmes 1989) bears a ventrally-projecting flange that extends into the subtemporal fossa in lateral or posterior view. The function of this flange remains unknown.

Unambiguous: Embolomeri (0 → 1).

206. Pterygoid, quadrate ramus, shagreen: absent (0), present (1).

Modified from J2025 (c323) and Brocklehurst et al. (2022, c148).

In *Westlothiana*, a shagreen of denticles covers the entire quadrate ramus of the pterygoid, a feature shared with other stem and basal crown tetrapods (e.g., *Acherontiscus*, Clack et al. 2019). In contrast, in total group-amniotes crownward of seymouriamorphs, the palatal dentition is generally restricted to the regions of the palatal process or transverse flange (e.g., microsaurs, Carroll and Gaskill 1978).

Unambiguous: *Doleserpeton* + Nectridea (1 → 0), *Erpetonyx* (0 → 1). DELTRAN: Tetrapoda (1 → 0).

207. Pterygoid, ascending dorsal lamina of the anterior (palatal) ramus: absent or low (0); tall (1).

FB2020 (c.148), Rea1992 (c.36), Bea1995 (c.45), Fea2011 (c.101), B2012 (c.116), Sea2018 (c.71).

An ascending lamina of the palatal ramus of the pterygoid is present in edaphosaurids (Reisz & Berman, 1986; Modesto, 1995) and sphenacodontids (Romer et al., 1940; Laurin, 1993), although due to the difficult nature of scoring the character it is unknown in many other synapsid taxa.

ACCTRAN: Synapsida (0 -> 1). DELTRAN: Edaphosauridae + Sphenacodontia (0 -> 1).

208. Interpterygoid vacuities: absent (0); present (1).

Rea2003 (c.153), RC2007 (c.160), Hea2013 (c.115), LR1997 (c.56), Lea1998 (c.54), A2001 (c.89), Cea2016 (c.159), Cea2019 (c.159). Modified from a division of Pea2017 (c.342, c.83).

Most ingroup taxa possess at least small interpterygoid vacuities, including the stem tetrapods *Pederpes* (Clack & Finney, 2005) and *Greererpeton* (Smithson, 1981), temnospondyls (e.g. Milner & Sequeira, Sigurdsen & Bolt, 2010), and microsaurs (Carroll & Gaskill, 1978) amongst others. However, a large number of taxa across a variety of clades have a closed palate, such as *Brachydectes* (Pardo et al., 2016), some seymouriamorphs (Berman et al., 2000; Kelmbara & Ruta, 2005) most stem tetrapods including embolomeres (Panchen, 1977; Holmes, 1989).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Phlegethontia linearis* (1 -> 0), *Vaughnitis smithae* (1 -> 0), *Dimetrodon sp.* (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), *Ariekanerpeton sigalovi* (0 -> 1), *Baphetes sp.* (1 -> 0), *Whatcheeria deltae* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), Adelospondyli (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0), *Chroniosaurus dongusensis* (0 -> 1). DELTRAN: *Acherontiscus caledoniae* (1 -> 0), *Belebey vegrandis* (1 -> 0),

Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0), Embolomeri (1 -> 0).

209. Total transverse width of interpterygoid vacuities, excluding cultriform process of parasphenoid, measured at widest extent of interpterygoid vacuities: less than half of total transverse palatal width at same level (0); at least half of total palatal transverse palatal width at same level (1).

Rea2003 (c.154), RC2007 (c.161), ML2019 (c.127).

In all temnospondyls more derived than *Edops* (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), as well as the nectrideans such as *Diploceraspis* (Beerbower, 1963), the palatal vacuities are distinctly wide relative to all other taxa, and are together at least half as wide as the whole palate at the same transverse level as their maximum width.

Unambiguous: *Diploceraspis sp.* (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1).

210. Interpterygoid vacuities concave along whole margins: no, at least partially convex (0); completely concave (1).

Rea2003 (c.155), RC2007 (c.162), ML2019 (c.128).

Unambiguous: *Westlothiana lizziae* (1 -> 0), *Petrolacosaurus kansensis* (1 -> 0), *Captorhinus aguti* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), Neoreptilia (1 -> 0), Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 0). DELTRAN: Tetrapoda (0 -> 1), *Lethiscus stocki* (1 -> 0), *Youngina capensis* (1 -> 0), *Paleothyris acadiana* (1 -> 0), *Ariekanerpeton sigalovi* (1 -> 0).

211. Maxilla - pterygoid contact: absent (0); present (1).

Novel

Unambiguous: *Oestocephalus sp.* (0 -> 1), *Tuditanus punctulatus* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

212. Denticle shagreen on palatal process of pterygoid: absent (0); present (1).

LR1997 (c.53), Lea1998 (c.51), A2001 (c.75), Cea2016 (c.103), Cea2019 (c.103), Hea2013 (c.97), Pea2017 (c.287).

Denticles on the palatal process of the pterygoid are present in stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) and are present in the majority of ingroup taxa. However, they are absent in many taxa from various clades, including *Gerobatrachus* (Anderson et al., 2008), *Anthracosaurus* (Panchen, 1977),

Vaughnitis (Brocklehurst et al., 2016), *Varanops* (Campione & Reisz, 2010), former "parareptiles" and *Youngina* (Got, 1972; 1974; Reisz et al., 2007) and *Orobates* (Berman et al., 2004). Within former "lepospondyls", they are also absent in the microsaurs *Cardiocephalus* (Carroll & Gaskill, 1978) and *Huskerpeton* (Huttenlocker et al., 2013), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and aïstopods (Carroll, 1998; Anderson, 2002; Pardo et al., 2017).

Unambiguous: Aïstopoda (1 -> 0), *Varanops brevirostris* (1 -> 0), *Vaughnitis smithae* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0), Neoreptilia (1 -> 0), *Orobates pabsti* (1 -> 0), *Anthracosaurus russelli* (1 -> 0), *Gerobatrachus hottoni* (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Euryodus sp.* (0 -> 1). DELTRAN: *Cardiocephalus sp.* (1 -> 0), *Huskerpeton englehorni* (1 -> 0).

213. Denticle shagreen on transverse process of pterygoid: absent (0); present (1); transverse flange of pterygoid absent (inapplicable).

Modified from a division of Pea2017 (c.288).

The presence of denticles on the transverse flange of the pterygoid is present in some seymouriamorphs (Klembara, 1997; Berman et al., 2000), as well as captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016) and protorothyridids (Carroll, 1964; 1969). They are also present in a small number of crown amniotes such as *Casea* (Olson et al., 1968), *Edaphosaurus* (Modesto, 1995) and *Haptodus* (Laurin, 1993).

Unambiguous: *Erpetonyx arsenaultorum* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (0 -> 1), *Orobates pabsti* (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), Caseidae (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1), Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 0). DELTRAN: Amniota + Diadectamorpha + Microsauria (1 -> 0), *Casea broilii* (0 -> 1), *Haptodus garnettensis* (0 -> 1), *Edaphosaurus boanerges* (0 -> 1).

214. Tooth row on transverse flange of pterygoid: absent (0); present (1); transverse flange of pterygoid absent (inapplicable).

Lea1998 (c.50, Rea2003 (c.142). Modified from a division of Pea2017 (c.288).

Unambiguous: Amniota (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0), *Limnoscelis paludis* (0 -> 1). ACCTRAN: Caseidae (1 -> 0), Edaphosauridae (1 -> 0), *Casea broilii* (1 -> 0), *Edaphosaurus boanerges* (1 -> 0).

215. Separately ossified ectopterygoid: absent (0); present (1).

LR1997 (c.48), Lea1998 (c.46), A2001 (c.92), Rea2003 (c.134), RC2007 (c.140), Pea2017 (c.259).

An ossified ectopterygoid is absent in the microsaur *Pantylus* (Carroll & Gaskill, 1978), and also in captorhinids (Fox & Bowman, 1966; Reisz et al, 2016).

Unambiguous: *Pantylus cordatus* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), *Scincosaurus crassus* (0 -> 1), *Lethiscus stocki* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (1 -> 0). DELTRAN: *Brachydectes newberryi* (1 -> 0), Diplocaulidae (1 -> 0), *Phlegethontia linearis* (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0).

216. Ectopterygoid narrowly wedged between palatine and pterygoid: no (0); yes (1).

Rea2003 (c.140), RC2007 (c.146).

This character describes a specific condition in which the palatine, pterygoid and maxilla entirely and tightly surround the ectopterygoid. The shape of the pterygoid and palatine are concave to fully encompass the ectopterygoid. This condition is observed in sphenacodontids (Romer & Price, 1940; Laurin, 1993) and *Edaphosaurus* (Modesto, 1995).

ACCTRAN: .Synapsida (0 -> 1). DELTRAN: Edaphosauridae + Sphenacodontia (0 -> 1).

217. Ectopterygoid maximum length (measured along long axis of element) relative to maximum length of palatine (measured along long axis of element): ectopterygoid shorter than palatine (0); ectopterygoid equal in length or longer than palatine (1).

Rea2003 (c.137), RC2007 (c.143), Cea2016 (c.71), ML2019 (c.115), Cea2019 (c.71), Pea2017 (c.260).

In the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and some other stem tetrapods (*Baphetes*, Beaumont, 1977), the ectopterygoid is a larger element than the palatine, or at least as big as the ectopterygoid as in *Greererpeton* (Smithson, 1981) and *Westlothiana*. This is also the condition present in temnospondyls (Milner & Sequeira, 1993; Arbez et al., 2022). In most crown amniotes and crownward stem amniotes (e.g. Romer et al., 1940; Gow, 1974; Reisz, 1977; Bolt & Scott, 1995; Ford & Benson, 2019), diadectamorphs (Romer, 1946; Berman et al., 1998; 2004), and several microsaurs (Carroll & Gaskill, 1978) the ectopterygoid has become substantially reduced in size.

Unambiguous: *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha, *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Acherontiscus caledoniae* (0 -> 1), *Lethiscus stocki* (0 -> 1), *Euryodus sp.* (0 -> 1), *Gerobatrachus hottoni* (1 -> 0).

218. Ectopterygoid - maxilla contact: absent (0); present (1).

Novel

Unambiguous: *Hyloplesion longicostatum* (1 -> 0), *Procynosuchus* (1 -> 0), *Youngina capensis* (1 -> 0). ACCTRAN: Reptilia (1 -> 0), Neoreptilia (0 -> 1). DELTRAN: *Scincosaurus crassus* (1 -> 0), *Archaeovenator hamiltonensis* (1 -> 0), *Orovenator mayorum* (1 -> 0).

219. Fangs on ectopterygoid: absent (0); present (1).

LR1997 (c.49), Lea1998 (c.47), Rea2003 (c.135), RC2007 (c.141), Cea2016 (c.92), ML2019 (c.116), Cea2019 (c.92), Pea2017 (c.283).

Fangs on the ectopterygoid, comparable in size or larger than the marginal dentition but significantly larger than the surrounding denticles, are present widely across stem tetrapods (Beaumont, 1977; Smithson, 1981). They are present in early temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Arbez et al., 2022), and stem amniotes such as *Gephyrostegus* (Klembara et al, 2014), seymouriamorphs (and anthracosaurs (Panchen, 1977; Holmes, 1989). They are absent in crownward temnospondyls and Nectrideans, microsaurs, (e.g. Carroll & Gaskill, 1978; Pardo et al., 2017; Milner, 2018) and amniotes (e.g. Reisz, 1977; Bolt & Scott, 1995; Ford & Benson, 2019), but are retained in *Westlothiana*.

ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Gephyrostegus bohemicus* (0 -> 1), Embolomeri (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: Amniota + Diadectamorpha + Microsauria (1 -> 0), Seymouriamorpha (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0), *Gerobatrachus hottoni* (1 -> 0).

220. Denticle shagreen on ectopterygoid: absent (0); present (1).

LR1997 (c.50), Lea1998 (c.48), Rea2003 (c.136), RC2007 (c.142), Kea2014 (c.67, c.69, c.72), Cea2016 (c.94, c.95), ML2019 (c.117), Cea2019 (c.94, c.95), Pea2017 (c.285).

Denticles on the ectopterygoid are widely present in several disparate clades from across the included taxa, including some stem tetrapods (Smithson, 1981; Clack & Finney, 2005, this study), some temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993), edaphosaurids (Modesto, 1995) and sphenacodontids (Romer et al., 1940), and *Orovenator* (Ford & Benson, 2019).

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), *Cardiocephalus sp.* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), *Araeoscelis gracilis* (0 -> 1), *Orovenator mayorum* (0 -

> 1), Embolomeri (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (1 -> 0), *Pederpes finneyae* (0 -> 1). ACCTRAN: Edaphosauridae + Sphenacodontia (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0). DELTRAN: *Dimetrodon sp.* (0 -> 1), *Edaphosaurus boanerges* (0 -> 1).

221. Row of at least three teeth on ectopterygoid, comparable in size to marginal teeth: absent (0); present (1).

Rea2003 (c.138), RC2007 (c.144), ML2019 (c.118), Cea2016 (c.93), Cea2019 (c.93), Pea2017 (c.284).

A row of teeth, larger than any surrounding denticles and more comparable in size to the marginal teeth, is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and the stem tetrapod *Greererpeton* (Smithson, 1981), but also in the former "lepospondyls" *Acherontiscus* (Clack et al, 2019) and *Euryodus* (Gee et al, 2019), *Micraroter* and *Cardiocephalus* (Carroll & Gaskill, 1978), all of which are microsaurs.

Unambiguous: Tetrapoda + *Baphetes sp.* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1). ACCTRAN: Adelospondyli (0 -> 1). DELTRAN: *Acherontiscus caledoniae* (0 -> 1).

222. Ectopterygoid reaches subtemporal fossa: absent (0), present (1).

Modified from Cea2019 (c72) and Rea2020 (c132).

Unambiguous: Embolomeri (1→ 0), Recumbirostra more derived than *Pantylus* (1 to 0).

223. Suborbital opening: absent (0); present (1).

FB2020 (c153), L1991 (c.A3), CC1991 (c.3), LR1995 (c.49), R1999 (c.43), M2004 (c.32), Rea2010 (c.48), Kea2014 (c.83), Mea2015 (c.79).

A suborbital opening in the palate, between the lateral skull bones, palatine and ectopterygoid, is a character noted in previous analyses to have united reptiles (Laurin & Reisz, 1995; Ford & Benson, 2019), a clade consisting of at least captorhinids, protorothyridids, araeoscelidians, younginiforms, and most former "parareptiles". It is present in former "parareptiles" (Gow, 1972; Reisz et al., 2007), *Youngina* (Gow, 1972), captorhinids (where it is linked with the absence of the ectopteryogoid; Fox & Bowman, 1966; Reisz et al., 2015; 2016) and araeoscelidians (Reisz, 1977; Reisz et al., 1984). It is also present in *Orovenator* (Ford & Benson, 2019), but not in synapsids such as *Archaeovenator* (Reisz & Dilkes, 2003).

Unambiguous: *Phlegethontia linearis* (0 -> 1), Araeoscelidia (0 -> 1), Neoreptilia (0 -> 1), Captorhinidae (0 -> 1), Seymouriamorpha (0 -> 1).

224. Anteroposterior position of jaw joint relative to occiput: jaw joint posterior to occiput (0); in line with occiput (1); anterior to occiput (2). (ordered).

LR1997 (c.6), Lea1998 (c.6), A2001 (c.70), Rea2003 (c.177), RC2007 (c.187), ML2019 (c.146), Cea2019 (c.222), Hea2013 (c.87), Pea2017 (c.75).

In most taxa, the position of the articulation between the mandible and the quadrate lies roughly in line with the occiput. Some clades, however, show a distinctly different position. In the outgroup and other stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) including *Westlothiana*, temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Arbez et al., 2022) and some diadectamorphs (Romer, 1946; Berman et al., 2004) the jaw articulation is posterior to the occiput, with the posterior skull margin sloping somewhat anterodorsally to posteroventrally. In nectrideans, the jaw articulation is anterior to the occiput (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018).

Unambiguous: *Cardiocephalus sp.* (1 -> 2), Varanopidae (1 -> 0), *Varanosaurus acutirostris* (1 -> 0), *Diadectes abistus* (0 -> 1), Seymouriamorpha (0 -> 1), *Archeria crassidisca* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + Microsauria(0 -> 1), Aïstopoda (1 -> 0), *Phlegethontia linearis* (0 -> 1), Diadectamorpha (1 -> 0). DELTRAN: *Lethiscus stocki* (1 -> 0), *Oestocephalus sp.* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1).

225. Dorsoventral position of jaw joint relative to toothrow: below (0); in line with (1); above (2). (ordered).

Pea2017 (c.98).

The jaw articulation is positioned ventrally to sit below the average level of the toothrow in a small number of basal microsaurs, namely *Tuditanus* and *Hyloplesion* (Carroll & Gaskill, 1978), some diadectamorphs (Romer, 1946; Berman et al., 2004), the seymouriamorph *Discosauriscus* (Klembara, 1997) and in edaphosaurids (Reisz et al., 1986; Modesto, 1995) and sphenacodontids (Romer et al., 1940; Laurin, 1993). When the toothrow is not straight, the average position is considered.

Unambiguous: *Lethiscus stocki* (1 -> 2), *Hyloplesion longicostatum* (1 -> 0), *Tuditanus punctulatus* (1 -> 0), *Pantylus cordatus* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0), *Varanosaurus acutirostris* (1 -> 2), *Araeoscelis gracilis* (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), *Discosauriscus austriacus* (1 -> 0), Temnospondyli (1 -> 2). ACCTRAN: Caseidae (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 0),

Diadectamorpha (1 -> 0), *Diadectes abistus* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (2 -> 1). DELTRAN: *Casea* broili ((1 -> 0), *Belebey vegrandis* (1 -> 0), *Orobates pabsti* (1 -> 0), *Limnoscelis paludis* (1 -> 0), *Doleserpeton annectens* (2 -> 1).

226. Quadrate dorsal process: absent, quadrate lacks dorsal process (0); present (1).

Rea2003 (c.98), RC2007 (c.100), ML2019 (c.80).

The process in question is recorded in dissorophoids (Ruta et al., 2003) and is hypothesised to have supported a cartilaginous tympanum in life. We observe that an ossified dorsal portion of the quadrate, expanding dorsally as a sheet or rod-like process from the ventral portion of the quadrate forming the jaw articulation, is not limited to temnospondyls, however, and is present in nearly all crown tetrapods within this matrix (Carroll & Gaskill, 1978; Romer, 1946; Berman et al., 1998) including captorhinids (Fox & Bowman, 1966; Reisz et al., 2016), former "parareptiles" (Gow, 1972; Reisz et al., 2007) and some synapsids (Laurin, 1993; Modesto, 1995). The dorsal process is absent in *Westlothiana*.

Unambiguous: *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + Microsauria (0 -> 1), Aïstopoda (1 -> 0).

227. Length of quadrate anterior process along articulation with pterygoid quadrate ramus: short, contacts pterygoid quadrate ramus along less than 55% of the length of the pterygoid quadrate ramus (0); long, contacts pterygoid quadrate ramus along more than 55% of the pterygoid quadrate ramus (1).

LR1995 (c.35).

This character was defined by Laurin & Reisz (1995) as if the quadrate anterior process is more or less than 55% of the quadrate ramus of the pterygoid. It is often difficult to score with confidence as this region has been reconstructed with some interpretation in many taxa, and is not often clearly preserved. Nonetheless, it was included here and scored where possible as it is a character stated to unite eureptilia in Laurin & Reisz (1995), where eureptilia are united by a quadrate anterior process (state 0). However, Laurin & Reisz (1995) included very few outgroup taxa, and so the basal condition was not well determined. In particular, their analysis defined synapsids as a single, functional taxonomic unit. A long quadrate anterior process is found in a small number of synapsids such as *Casea* (Olson et al., 1968) and *Dimetrodon* (Romer et al., 1940), as well as *Gephyrostegus* (Klembara et al., 2014) and seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005).

Unambiguous: Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Edops craigi* (0 -> 1). ACCTRAN: Synapsida (0 -> 1), Edaphosauridae (1 -> 0). DELTRAN: *Casea broilii* (0 -> 1), *Dimetrodon sp.* (0 -> 1).

228. Stapes, dorsal process expands distally: absent (0), present (1).

LR1997 (c.79), Lea1998 (c.76), A2001 (c.85), Hea2013 (c.111), Pea2017 (c.223).

Unambiguous: *Procynosuchus delaharpeae* (1 -> 0), Aïstopoda (1 -> 0), *Micraroter erythrogeois* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Araeoscelidia (1 -> 0), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0). DELTRAN: *Brachydectes newberryi* (0 -> 1), *Araeoscelis gracilis* (1 -> 0), *Youngina capensis* (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1).

229. Stapes dorsal process: absent (0); present (1).

230. Shape of proximal stapedial footplate: oval (0); round (1).

LR1997 (c.80), L1998 (c.77), A2001 (c.84), Hea2013 (c.110), Pea2017 (c.243).

Unambiguous: *Euryodus sp.* (0 -> 1), Sphenacodontia (0 -> 1). ACCTRAN: *Recumbirostra*(0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), Synapsida (1 -> 0). DELTRAN: *Micraroter erythrogeois* (0 -> 1), *Hapsidopareion lepton* (0 -> 1), Neoreptilia (0 -> 1), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (0 -> 1).

231. Stapes columella perforated by stapedial foramen: no, stapes is imperforate (0); yes (1).

LR1997 (c.81), Lea1998 (c.78), A2001 (c.83), Hea2013 (c.108), Pea2017 (c.241)

Unambiguous: *Microbrachis pelikani* (0 -> 1), *Euryodus sp.* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (1 -> 0). ACCTRAN: *Brachydectes newberryi* (0 -> 1).

232. Stapes orientation: dorsal, towards tabular or posterior emargination (0); anteroventral, towards quadrate (1).

Hea2013 (c.109), Pea2017 (c.242)

Unambiguous: *Edops craigi* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + Microsauria (0 -> 1), Aïstopoda (1 -> 0), *Doleserpeton annectens* (0 -> 1).

233. Adductor crest on mandible: absent, dorsal margin of mandible is smooth (0); present (1).

Pea2017 (c.296).

The dorsal margin of the jaw is smooth in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and in other stem tetrapods (Beaumont, 1977; Smithson, 1981) including *Westlothiana*. In the anthracosaur *Archeria* (Holmes, 1989) and the stem amniote *Silvanerpeton* (Ruta & Clack, 2006), the dorsal margin forms a distinct, raised adductor crest. This condition is present in most amniote taxa crownwards of this including most former "lepospondyls" (Beerbower, 1963; Carroll & Gaskill, 1978; Andrews & Carroll, 1991; Milner & Ruta, 2009), diadectamorphs (Romer, 1946; Berman et al., 1998; 2004), *Paleothyris* (Carroll, 1969), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015) and most crown amniotes (e.g. Gow, 1972; Laurin, 1993; Bolt & Scott, 1995; Modesto, 1995; Spindler, 2016; Ford & Benson, 2019) This is absent in aïstopods (Carroll, 1998; Anderson, 2002; Pardo et al., 2017), which have a reduced mandible with a small number of ossifications. An adductor crest is also gained in a small number of other taxa.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (0 -> 1), Aïstopoda (1 -> 0), *Varanops brevirostris* (1 -> 0), *Eothyris parkeyi* (1 -> 0), *Archeria crassidisca* (0 -> 1), *Balanerpeton woodi* (0 -> 1).

234. Elements forming adductor crest: surangular only (0); posterior coronoid and surangular (1); dentary (2).

Novel

This character describes the elements that, in lateral view, are the dominant contribution to the dorsalmost point of the adductor crest. Where multiple elements meet at the dorsalmost point of the crest, and contribute relatively equally, such taxa have been scored as multistate. In the majority of microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2019; 2021) and diplocaulid nectrideans (Douthitt, 1917; Beerbower, 1963) the dentary is the dominant element forming the adductor crest. There is no clear phylogenetic signal within amniotes more crownwards of former "lepospondyls".

Unambiguous: *Brachydectes newberryi* (2 -> 1), *Pantylus cordatus* (2 -> 1), .Synapsida (1 -> 2), *Araeoscelis gracilis* (1 -> 2). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Adelospondyli (2 -> 0), Varanopidae (2 -> 0), *Limnoscelis paludis* (1 -> 0), *Ariekanerpeton sigalovi* (1to(0 2)), Temnospondyli (0 -> 2). DELTRAN: *Acherontiscus caledoniae* (2 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), *Aerosaurus wellesi* (2 -> 0), *Paleothyris acadiana* (1 -> 2), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), *Discosauriscus austriacus* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1), *Balanerpeton woodi* (0 -> 2).

235. Elements contributing to mandibular symphysis: dentary alone (0); dentary and splenial (1).

Hea2013 (c.139), A2001 (c.109), Pea2017 (c.101).

Unambiguous: *Pantylus cordatus* (0 -> 1), Varanopidae (1 -> 0), Temnospondyli except *Edops craigi* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), Nectridea (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Amniota (1 -> 0), .Synapsida (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1). DELTRAN: Diplocaulidae (0 -> 1), *Varanosaurus acutirostris* (1 -> 0), *Araeoscelis gracilis* (1 -> 0), Reptilia (1 -> 0), *Discosauriscus austriacus* (1 -> 0), *Gephyrostegus bohemicus* (1 -> 0).

236. Mandibular symphysis: thin, tapering anteriorly (0), thick, mandibular symphysis almost as deep as mandible at mandibular midlength (1).

J2025(c. 536).

237. Number of Meckelian fossae: none (0); one (1); two or more (2) (ordered).

Pea2017 (c.94), A2001 (c.100), Hea2013 (c.130).

Most included taxa show a single meckelian fossa on the medial surface of the mandible (e.g. Fox & Bowman, 1966; Gow, 1972; Smithson, 1981; Bolt & Scott, 1995; Berman et al., 2004; Sigurdsen & Bolt, 2010; Pardo et al., 2017). An absence of any meckelian fossae is seen in some microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013), and sphenacodontids (Romer et al., 1940; Laurin, 1993), as well as a small number of other taxa including the aïstopod *Phlegethontia* (Anderson, 2002) and the parareptile *Belebey* (Reisz et al., 2007). Many stem tetrapods including *Archeria* (Holmes, 1989), *Westlothiana*, and the enigmatic *Caerorachis* (Ruta et al, 2001) show two or more fossae.

Unambiguous: *Diplocaulus sp.* (1 -> 2), *Phlegethontia linearis* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), Sphenacodontia (1 -> 0), *Archeria crassidisca* (1 -> 2), *Caerorachis* (1 -> 2), *Balanerpeton woodi* (1 -> 2). ACCTRAN: Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 2), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (2 -> 1). DELTRAN: *Seymouria sanjuanensis* (1 -> 2), *Gephyrostegus bohemicus* (1 -> 2).

238. Meckelian canal, exposure: restricted to posterior half of skull, margins formed by meckelian ossification or prearticular (0), open meckelian fenestra extends anteriorly more than half the length of the mandible, with extensive contribution by splenial and/or postsplenial (1).

Modified from Pea2017 (c95).

Unambiguous: *Westlothiana* (0 to 1). ACCTRAN: Tetrapoda (1 → 0).

239. Retroarticular process: absent (0); present (1).

A2001 (c.102), Hea2013 (c.132), Pea2017 (c.96).

A retroarticular process, extending posteriorly from the articular articulation with the quadrate, is present in a variety of clades including *Hylonomus* (Carroll, 1964), *Captorhinus* (Fox & Bowman, 1966), the former "parareptiles" *Erpetonyx* (Modesto et al., 2015) and *Belebey* (Reisz et al., 2007), and many synapsids (e.g. Bolt & Scott, 1995; Campione & Reisz, 2010; Spindler, 2016). A retroarticular process is also found widely across former "lepospondyls", including adelogyrinids (Andrews & Carroll, 1991; Clack et al., 2019), some nectrideans (Beerbower, 1963; Milner & Ruta, 2009), and some microsaurs such as *Tuditanus*, *Pantylus*, *Microbrachis* (Carroll & Gaskill, 1978) and *Llistrofus* (Gee et al., 2019). Although absent in the small number of temnospondyl OTUs within this dataset, a robust, Nectridean-like retroarticular process is present in brachypoid temnospondyls (Ruta and Bolt 2007).

Unambiguous: *Utaherpeton franklini* (1 -> 0), *Diplocaulus sp.* (1 -> 0), Aïstopoda (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), *Belebey vegrandis* (1 -> 0), *Captorhinus aguti* (0 -> 1), *Hylonomus lyelli* (0 -> 1), *Diadectes abistus* (0 -> 1). ACCTRAN: Amniota (0 -> 1), Araeoscelidia (1 -> 0). DELTRAN: Synapsida (0 -> 1), Reptilia (0 -> 1).

240. Mandible, retroarticular process, orientation: posteriorly directed (0); upturned posterodorsally (1); curves posteroventrally (2) inapplicable process is absent (inapplicable).

FB2020 (c173). Modified from Gea1988 (c.105), D1998 (c.75), M2004 (c.101), B2012 (c.133).

A posteroventrally curving retroarticular process is distinctly present in sphenacodontids (Romer et al., 1940; Laurin, 1993; Ford & Benson, 2019).

Unambiguous: *Scincosaurus crassus* (0 -> 1), *Westlothiana lizziae* (0 -> 1), *Varanops* (0 -> 1), Sphenacodontia (0 -> 2).

241. Mandibular canal exposure: entirely enclosed, opens through lines of pores (0), partially enclosed with grooves and pores (1), entirely open (2). (ordered).

Modified from Pea2017 (c307).

242. Meckelian bone ossified in middle part of jaw: absent (0), present (1).

Modified from Pea2017 (c310).

Unambiguous: Aistopoda (0 to 1), Tetrapodomorphs more derived than *Whatcheeria* (1 to 0).

243. Oral sulcus/surangular pit line of mandible: absent (0), present (1)

Modified from Pea2017 (c308).

Unambiguous: Tetrapodomorpha more derived than Adelospondylidae (0 to 1).

244. Surangular, lateral exposure: elongate, extending anterior to coronoid eminence (0), reduced, not extending anterior to coronoid eminence (1).

Modified from Pea2017 (c90).

Unambiguous: Nastrondormes (0 → 1), *Lethiscus* (0 to 1).

245. Mandible, anterodorsal curvature of anterior mandible in lateral view: absent, alveolar margin of anterior mandible approximately horizontal (0); present, dorsal margin of anterior mandible shows distinct concavity (1).

FB2020 (c.165).

A distinct curvature of the dorsal margin of the mandible is distinctly present in derived sphenacodontids (Romer et al., 1940; Spindler, 2016; Ford & Benson, 2019), in which it corresponds with a large ventral curvature of the maxilla. A similar condition is present in a variety of other taxa including *Whatcheeria* (Rawson et al., 2021), *Archeria* (Holmes, 1989), some other synapsids (e.g. Bolt & Scott, 1995; Mann & Paterson, 2020), *Hylonomus* (Carroll, 1964), *Gephyrostegus* (Klembara et al., 2014), *Seymouria* (Berman et al., 2000), *Brachydectes* (Pardo et al., 2016) and *Westlothiana*.

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Westlothiana lizziae* (0 -> 1), *Echinerpeton intermedium* (0 -> 1), Sphenacodontia (0 -> 1), *Varanosaurus acutirostris* (0 -> 1), *Hylonomus lyelli* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Caerorachis bairdi* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0). DELTRAN: *Seymouria sanjuanensis* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

246. Dentary ventral edge shape: smooth continuous line (0); abruptly tapering or "stepped" margin (1).

Cea2016 (c.133), Cea2019 (c.133), Pea2017 (c.304).

This character describes a condition in which the ventral margin of the dentary turns upwards with a sharp angle, rather than a smooth curve. A sharp angle is present sporadically in *Adelogyrinus* (Andrews & Carroll, 1991), *Lethiscus* (Pardo et al, 2017), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015; 2016), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009) and some microsaurs including *Tuditanus*, *Pantylus*, and *Microbrachis* (Carroll & Gaskill, 1978).

Unambiguous: *Acherontiscus caledoniae* (1 -> 0), *Oestocephalus sp.* (1 -> 0), *Hyloplesion longicostatum* (1 -> 0), Captorhinidae (0 -> 1), *Balanerpeton woodi* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), Caseasauria (0 -> 1), Seymouriamorpha (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1). DELTRAN:*Cardiocephalus sp.* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Eothyris parkeyi* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

247. Dentary, anterior end, chin-like process projecting anteriorly beyond tooth row: absent (0), present (1).

Modified from Cea2019 (c215).

Unambiguous: Adelospondylidae (0 → 1).

248. Teeth on the dentary: absent (0); present (1).

Rea2003 (c.186), RC2007 (c.196), ML2019 (c.154).

There are no taxa in this analysis in which dentary teeth are absent. However, due to the inclusion of this character in the large matrices of Ruta & Coates (2007) and Marjanovic & Laurin (2019) this character is retained to allow for future inclusion of taxa in which dentary teeth are absent, particularly for further expansion into amphibians, as teeth are absent on the dentary in salientians (Ruta et al., 2003).

249. Number of dentary teeth: fewer than 14 (0); 15-19 (1); 20-29 (2); more than 29 (3).(ordered).

Cea2016 (c.130), Cea2019 (c.130).

The states for this character were chosen to represent phylogenetic distributions. Most stem tetrapods (Beaumont, 1977, Smithson, 1981) including *Archeria* (Holmes, 1989) and *Silvanerpeton* (Ruta & Clack, 2006), and stem amniotes *Gephyrostegus* (Klembara et al., 2014) and seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005) possess at least of 29 teeth. Protorothyridids possess at least 35 teeth (Carroll, 1964; 1969), and within araeoscelidians *Petrolacosaurus* possesses around 29 (Reisz, 1977) but *Araeoscelis* has just 18 (Reisz et al., 1984). Captorhinids, similarly, show a variety, with more than 30 in *Captorhinus* (Fox & Bowman, 1966), *Euconcordia* has 17 (Reisz et al., 2016) and *Opisthodontosaurus* has just 10 (Reisz et al., 2015). Most synapsids crownwards of this have between 20 and 30 dentary teeth (e.g. Romer et al., 1940; Modesto, 1995; Reisz et al., 2009), although there are exceptions with both more and less, such as *Varanosaurus* with as many as 60 teeth (Bolt & Scott, 1995) or *Casea* with 12 teeth (Olson et al., 1968). Varanopids (Langston & Reisz, 1981; Campione & Reisz, 2010) along with *Archaeovenator* (Reisz & Dilkes, 2003) and *Orovenator* (Ford & Benson, 2019), have at least 30 teeth. Temnospondyls possess a very high number of dentary teeth, ranging from 35 to upwards of 60 (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022). The choice of 14 as the lower bound was chosen to differentiate diadectamorphs and nectrideans. No diadectamorphs have fewer than 15 teeth (Romer, 1946; Berman et al., 1998; 2004), and typically nectrideans have more than 14 (Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), although *Diplocaulus* has in excess of 30 (Douthitt, 1917).

Unambiguous: *Acherontiscus caledoniae* (3 -> 1), *Diplocaulus sp.* (0 -> 3), *Phlegethontia linearis* (3 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (2 -> 1), *Procynosuchus delaharpeae* (2 -> 1), Araescelis gracilis (3 -> 1), Neoreptilia (3 -> 0), *Opisthodontosaurus carrolli* (3 -> 0), *Euconcordia cunninghami* (3 -> 1), Diadectamorpha (3 -> 1), *Solenodonsaurus janenschi* (3to2). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (2 -> 3), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Huskerpeton englehorni* (0 -> 1), Synapsida (3to2), Varanopidae (2 -> 3), Caseidae (2 -> 0). DELTRAN: Tetrapoda + *Baphetes sp.* (2 -> 3), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0), Caseasauria + *Echinerpeton intermedium* (3to2), *Casea broilii* (2 -> 0), Edaphosauridae + Sphenacodontia (3 -> 2).

250. Dentary accessory tooth row: absent, dentary has no teeth or just a single tooth row (0); present (1).

Rea2003 (c.182), RC2007 (c.192).

More than one row of teeth on the dentary, in parallel with each other for at least part of the length of the dentary, is classically associated with *Captorhinus* (Fox & Bowman, 1966). However, it is also noted in the microsaur *Euryodus* (Gee at al, 2019). An additional tooth row has been noted in the Nectridean *Diplocaulus*, but personal study of specimens across the AMNH suggests that these instead correspond to a large coronoid tooth row as in *Diploceraspsis* (Beerbower, 1963).

Unambiguous: *Diplocaulus sp.* (0 -> 1), *Scincosaurus crassus* (0 -> 1), *Euryodus sp.* (0 -> 1), *Captorhinus aguti* (0 -> 1).

251. Anteroposterior length of dentary tooth row relative to total anteroposterior length of jaw: tooth row is under 50% of jaw (0); tooth row is more than 50% of jaw (1).

Pea2017 (c.88).

A short toothrow on the dentary is present in *Captorhinus* (Fox & Bowman, 1966) and *Euconcordia* (Reisz et al., 2016) but is also widespread across former "lepospondyls", being present in *Brachydectes* (Pardo et al., 2016), the nectrideans *Diploceraspis* (Beerbower, 1963) and *Keraterpeton* (Milner & Ruta, 2009) and most microsaurs (Carroll & Gaskill, 1978, Gee et al., 2019).

Unambiguous: *Diplocaulus sp.* (0 -> 1). *Limnoscelis paludis* (1 -> 0). (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni* (0 -> 1), *Cardiocephalus sp.* (1 -> 0), Captorhinidae (1 -> 0), *Opisthodontosaurus carrolli* (0 -> 1). DELTRAN: *Adelogyrinus simorhynchus* (0 -> 1), Aïstopoda (0 -> 1), *Euryodus sp.* (0 -> 1), *Huskerpeton englehorni* (0 -> 1), *Captorhinus aguti* (1 -> 0), *Euconcordia* (1 -> 0).

252. Dentary fangs lingual to marginal dentary tooth row: absent (0); present (1).

Rea2003 (c.183). Modified from a division of RC2007 (c.193), Cea2016 (c.129), ML2019 (c.151), Cea2019 (c.129), Pea2017 (c.332).

Stem tetrapods (Beaumont, 1977; Smithson, 1981; Rawson et al., 2021) and temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022) possess symphyseal fangs on the dentary, close to the anterior margin of the jaw, and lingual to the toothrow.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0).

253. Size of dentary teeth relative to maxillary teeth: dentary teeth are smaller or equal in size to maxillary teeth (0); dentary teeth are larger than maxillary teeth (1).

Rea2003 (c.221), RC2007 (c.231), ML2019 (c.185). Modified from Cea2019 (c.250), Pea2017 (c.333).

Large dentary teeth, larger in height than the teeth on the maxilla, occur in many temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), and a small number of other taxa including *Araeoscelis* (Reisz et al., 1984), *Captorhinus* (Fox & Bowman, 1966) and the microsaur *Micraroter* (Carroll & Gaskill, 1978).

Unambiguous: *Micraroter erythrogeois* (0 -> 1), *Araeoscelis gracilis* (0 -> 1), *Captorhinus aguti* (0 -> 1). ACCTRAN: Temnospondyli (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1).

254. Separately ossified postsplenial: absent (0); present (1).

LR1997 (c.87), Lea1998 (c.84), Rea2003 (c.191), RC2007 (c.201), ML2019 (c.157).

Two separately ossified splenial elements are present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021), other stem tetrapods (Beaumont, 1977; Smithson, 1981), *Westlothiana*, temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), and most microsaurs (Carroll & Gaskill, 1978; Gee et al., 2021). A second splenial, the postsplenial, is lost in most non-microsaur former "lepospondyls" (e.g. Milner & Ruta, 2009; Pardo et al., 2017), and all stem and crown amniotes crownwards of microsaurs including diadectamorphs (e.g. Romer, 1946; Fox & Bowman, 1966; Carroll, 1969; Reisz, 1977; Bolt & Scott, 1995; Berman et al., 1998; 2004; Campione & Reisz, 2010; Ford & Benson, 2019).

Unambiguous: Aïstopoda (1 -> 0), *Diplocaulus sp.* (0 -> 1), *Huskerpeton englehorni* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0). ACCTRAN: *Hapsidopareion lepton* (1 -> 0). DELTRAN: *Hapsidopareion lepton* (1 -> 0).

255. Postsplenial pit line: absent (0), present (1).

Modified from Pea2017 (c317).

256. Postsplenial, mesial lamina: absent (0), present (1).

Modified from Pea2017 (c316).

Unambiguous: Embolomeri + Baphetidae + *Silvanerpeton* + *Caerorachis* + Tetrapoda

257. Splenial exposed in lateral view: no (0); yes (1).

Hea2013 (c.129), Pea2017 (c.93), A2001 (c.98).

A lateral exposure of the splenial and/or postsplenial occurs in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and in most other stem tetrapods (Beaumont, 1977; Smithson,

1981) and stem amniotes including, and stewards of, diadectamorphs (Romer, 1946; Berman et al., 1998; 2004; Ruta & Clack, 2006). The splenial lateral exposure is absent in some temnospondyls (Arbez et al., 2022), some former "lepospondyls" (Beerbower, 1963; Carroll & Gaskill, 1978; Carroll, 1998; Pardo et al., 2017), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), some synapsids (Bolt & Scott, 1995; Brocklehurst et al., 2016), and reptiles including former "parareptiles" (Gow, 1972; Reisz & Dilkes, 2003; Reisz et al., 2007; Modesto et al., 2015; Ford & Benson, 2019).

Unambiguous: Aïstopoda (1 -> 0), *Diploceraspis sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Aerosaurus wellesi* (1 -> 0), *Vaughnitis smithae* (1 -> 0), *Varanosaurus acutirostris* (1 -> 0). ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), Synapsida (0 -> 1), *Euconcordia cunninghami* (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (1 -> 0). DELTRAN: Reptilia (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), *Paleothyris acadiana* (1 -> 0), *Archeria crassidisca* (1 -> 0), *Dendrerpeton helogenes* (1 -> 0).

258. Splenial, mesial lamina: absent (0), present (1).

Modified from Cea2019 (c152).

259. Parasymphyseal tooth plate: absent (0), present (1).

Modified from Cea2019 (c. 40) and Rea2020 (c164).

A parasymphyseal tooth plate is widespread among stem tetrapods, including aistopods and *Westlothiana*, but is absent in the crown group (Pardo et al. 2017).

Unambiguous: Tetrapoda (1 to 0).

260. Separately ossified anterior coronoid: absent (0); present (1).

LR1997 (c.83), Lea1998 (c.80), Rea2003 (c.202), RC2007 (c.212), ML2019 (c.167).

The absence of an anterior coronoid is observed in captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), the stem reptile *Orovenator* (Ford & Benson, 2019), and former "parareptiles" (Gow, 1972; Reisz et al., 2007) and *Petrolacosaurus* (Reisz, 1977). In these taxa, the number of coronoids is reduced to one (although in captorhinids, an anterior coronoid may be fused with the posteriormost coronoid or remain a separate ossification, e.g., OMNH 44816), which is considered here to be the posterior coronoid based on its position. An anterior coronoid is present in *Westlothiana*.

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Phlegethontia linearis* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0). ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1 -> 0), Synapsida (0 -> 1), *Limnoscelis paludis* (0 -> 1). DELTRAN: *Petrolacosaurus kansensis* (1 -> 0), Reptilia (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), *Diadectes abistus* (1 -> 0).

261. Separately ossified middle coronoid: absent (0); present (1).

LR1997 (c.84), Lea1998 (c.81), Rea2003 (c.206), RC2007 (c.216), ML2019 (c.171).

A middle coronoid is lost in most reptiles, captorhinids and *Petrolacosaurus* as these taxa retain just one coronoid (see ch.180). However, a middle coronoid is also lost in synapsids (e.g. Bolt & Scott, 1995; Campione & Reisz, 2010; Brocklehurst et al., 2016), which retain two coronoids, considered to be anterior and posterior based on position. It is present in *Westlothiana*.

Unambiguous: Aïstopoda (1 -> 0), *Huskerpeton englehorni* (1 -> 0), *Greererpeton burkemorani* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Limnoscelis paludis* (0 -> 1). DELTRAN: *Westlothiana lizziae* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Diadectes abistus* (1 -> 0).

262. Separately ossified posterior coronoid: absent (0); present (1).

LR1997 (c.85), Lea1998 (c.82), Rea2003 (c.210), RC2007 (c.220), ML2019 (c.175).

A posterior coronoid is lost in the aïstopods *Lethiscus* (Pardo et al, 2017) and *Phlegethontia* (Anderson, 2002), in which the mandible is reduced to a small number of ossifications. A posterior coronoid is present in *Westlothiana*.

ACCTRAN: Aïstopoda (1 -> 0). DELTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0).

263. Posterodorsal process on posterior coronoid: absent (0); present (1).

Rea2003 (c.214), RC2007 (c.224), Cea2016 (c.120), Cea2019 (c.121), Pea2017 (c.301). Modified from a division of ML2019 (c.179).

The posterior coronoid sends a backward process detaching immediately posterolateral to its main (sometimes dentigerous) part and contributing in various degrees to the anterolateral portion of the adductor fossa in the majority of stem and crown amniotes crownwards of *Silvanerpeton*, including seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2006), most former "lepospondyls" (e.g. Beerbower, 1973; Carroll & Gaskill, 1978), most diadectamorphs (Romer, 1946, Berman et al, 1998) and crown amniotes (e.g. Reisz, 1977; Bolt & Scott, 1995; Reisz & Dilkes, 2003). However, it is absent in *Westlothiana* and

Orobates (Berman et al., 2004). It is also noted to be present in *Caerorachis* (although the reconstruction figured by Ruta et al., 2001 lacks such a process) and *Dendrerpeton* (Arbez et al., 2022).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Westlothiana lizziae* (1 -> 0), *Orobates pabsti* (1 -> 0), *Caerorachis bairdi* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1).

264. Posterodorsal process of posterior coronoid contributing to tallest point of lateral margin of adductor fossa: no (0), yes (1).

Rea2003 (c.216), RC2007 (c.226). Modified from a division of ML2019 (c.179).

This refers to the extension, backward and dorsalward, of the process referred to in ch.217. In some taxa, the latter forms part of the tallest point of the lateral margin of the adductor fossa, regardless of the presence of absence, in the surangular, of a 'crest' (that is, a peak in the dorsal margin of the surangular) such as in temnospondyls (Romer & Witter, 1942; Arbez et al., 2021), synapsids (e.g. Bolt & Scott, 1995; Campione & Reisz, 2010) and reptiles (Gow, 1972; Ford & Benson, 2019).

Unambiguous: Temnospondyli (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Microbrachis pelikani* (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Limnoscelis paludis* (1 -> 0), *Ariekanerpeton sigalovi* (1 -> 0), *Gephyrostegus bohemicus* (1 -> 0). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), *Diadectes abistus* (0 -> 1), *Discosauriscus austriacus* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1).

265. Posterior coronoid exposed in lateral view: no (0); yes (1).

Rea2003 (c.215), RC2007 (c.225), Cea2016 (c.122), ML2019 (c.180), Cea2019 (c.122), Pea2017 (c.302).

In some taxa, the posterior coronoid is visible in lateral view as either a sliver or a more substantial lappet of bone tightly appressed against the surangular and posterodorsal to the posterior ramus of the dentary, including *Brachydectes* (Pardo et al., 2016), *Petrolacosaurus* (Reisz, 1977), *Diadectes* (Berman et al., 1998) and *Gephyrostegus* (Klembara et al., 2014).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Diadectes abistus* (0 -> 1), Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Ariekanerpeton sigalovi* (1 -> 0). ACCTRAN: Reptilia (0 -> 1), *Milleropsis pricei* (1 -> 0), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). DELTRAN: *Belebey vegrandis* (0

-> 1), *Orovenator mayorum* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1).

266. Anterior coronoid - splenial contact: absent (0); present (1); anterior coronoid absent (inapplicable).

Novel

In almost all taxa included in this analysis, the anterior coronoid and the splenial make contact. In *Westlothiana*, the splenial is a narrow, rod-like element restricted to a ventral postion, and the anterior coronoid is also narrow and restricted to a particularly dorsal position. A similar condition is observed in *Acherontiscus* (Clack et al, 2019).

Unambiguous: *Westlothiana lizziae* (1 -> 0). ACCTRAN: Adelospondyli (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (1 -> 0).

267. Middle coronoid - splenial contact: absent (0); present (1); middle coronoid absent (inapplicable).

Novel

In some taxa, as discussed in ch.220, the splenial possesses a ventral position and the coronoids are dorsoventrally narrow and dorsally located. However, in several taxa, such as *Gephyrostegus* (Klembara et al, 2014), the splenial is taller and extends dorsally to contact the middle coronoid. Such a condition is also observed in *Greererpeton* (Smithson, 1981), the temnospondyls *Balanerpeton* (Milner & Sequeira, 1993) and *Dendrerpeton* (Arbez et al., 2022), the anthracosaur *Archeria* (Holmes, 1989), the seymouriamorph *Discosauriscus* (Klembara, 1997) and the microsaurs *Pantylus* (Carroll & Gaskill, 1978) and *Euryodus* (Gee et al., 2021).

Unambiguous: Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1), *Archeria crassidisca* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Recumbirostra*(0 -> 1). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1), *Greererpeton burkemorani* (0 -> 1).

268. Fangs on anterior coronoid (recognisable as at least twice the height of coronoid teeth): absent (0); present (1); anterior coronoid absent (inapplicable).

Rea2003 (c.203), RC2007 (c.213), ML2019 (c.168). Modified from a division of LR1997 (c.92), Lea1998 (c.88), Cea2016 (c.123), Cea2019 (c.124), Pea2017 (c.326, c.327).

In the included taxa, *Gephyrostegus* is noted to have a large fang, clearly larger than the surrounding denticles and comparable in size to the marginal teeth, on both the anterior and middle coronoids (Klembara et al., 2014).

Unambiguous: *Gephyrostegus bohemicus* (0 -> 1).

269. Fangs on middle coronoid (recognisable as at least twice the height of coronoid teeth): absent (0); present (1); middle coronoid absent (inapplicable).

Rea2003 (c.207), RC2007 (c.217), ML2019 (c.172).

See ch. 222.

Unambiguous: *Gephyrostegus bohemicus* (0 -> 1).

270. Fangs on posterior coronoid (recognisable as at least twice the height of coronoid teeth): absent (0); present (1); posterior coronoid absent (inapplicable).

Rea2003 (c.211), RC2007 (c.221), ML2019 (c.176).

No taxa other than *Eusthenopteron* in the current analysis possess fangs on the posterior coronoid, but the character is retained in order to allow for expansion of the future analysis to include deeper stem tetrapod taxa including more panderichthyids, some of which possess posterior coronoid fangs (Ruta et al., 2003).

271. Denticles forming shagreen or discrete patches on anterior coronoid: absent (0); present (1); anterior coronoid absent (inapplicable).

Rea2003 (c.204), RC2007 (c.214), ML2019 (c.169). Modified from a division of LR1997 (c.93), Lea1998 (c.89), Cea2016 (c.126, c.127), Cea2019 (c.127, c.127), Pea2017 (c.329).

A small number of disparate taxa possess a denticle shagreen on the anterior coronoid. While present in temnospondyls (Romer & Witter, 1942; Milner & Sequeira, 1993; Arbez et al., 2022), anthracosaurs (Panchen, 1977; Holmes, 1989), seymouriamorphs (Kelmbara, 1997; Berman et al., 2000; Klembara & Ruta, 2005) and *Limnoscelis* (Romer, 1946), such a shagreen is largely absent in former "lepospondyls" or crown amniotes, with the exception of *Microbrachis* (Carroll & Gaskill, 1978) and *Edaphosaurus* (Modesto, 1995). They are present in *Westlothiana*.

ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), *Microbrachis pelikani* (0 -> 1), Amniota (1 -> 0), Edaphosauridae (0 -> 1). DELTRAN: Tetrapoda (0 -> 1), Aïstopoda (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni + Micraroter erythrogeois* (1 -> 0), Synapsida (1 -> 0), *Edaphosaurus boanerges* (0 -> 1).

272. Denticles forming shagreen or discrete patches on middle coronoid: absent (0); present (1); middle coronoid absent (inapplicable).

Rea2003 (c.208), RC2007 (c.215), ML2019 (c.173). Modified from a division of LR1997 (c.93), Lea1998 (c.89), Cea2016 (c.126, c.127), Cea2019 (c.127, c.127), Pea2017 (c.329).

As is the case for ch.225, denticles on the middle coronoid have a scattered distribution across a number of disparate tetrapods. They are present in *Greererpeton* (Smithson, 1981), temnospondyls (Romer & Witter, 1940; Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), anthracosaurs (Panchen, 1977; Holmes, 1989) seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005), *Gephyrostegus* (Klembara et al., 2014), *Limnoscelis* (Romer, 1946) and *Westlothiana*.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), Adelospondyli (0 -> 1), Diadectamorpha (0 -> 1). DELTRAN: *Acherontiscus caledoniae* (0 -> 1), *Vaughnitis smithae* (1 -> 0).

273. Denticles forming shagreen or discrete patches on posterior coronoid: absent (0); present (1); posterior coronoid absent (inapplicable).

Rea 2003 (c.212), RC2007 (c.222), ML2019 (c.177). Modified from a division of LR1997 (c.93), Lea1998 (c.89), Cea2016 (c.126, c.127), Cea2019 (c.127, c.127), Pea2017 (c.329).

The distribution of states in this character is almost exactly co-distributed with ch.226. However, there are a small number of differences. *Doleserpeton* possesses denticles on the middle coronoid but not the posterior coronoid (Sigurdsen & Bolt, 2010). *Edaphosaurus* (Modesto, 1995) and *Haptodus* (Laurin, 1993) both have denticles on the posterior coronoid but lack a middle coronoid altogether. A shagreen of denticles is present on the posterior coronoid in *Westlothiana*.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), Adelospondyli (0 -> 1), *Westlothiana lizziae* (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1), Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 0), *Limnoscelis paludis* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Haptodus garnettensis* (0 -> 1), *Edaphosaurus boanerges* (0 -> 1), *Diadectes abistus* (1 -> 0), *Doleserpeton annectens* (1 -> 0).

274. Tooth row on anterior coronoid: absent (0); present (1); anterior coronoid absent (inapplicable).

RC2007 (c.215), Rea2003 (c.205), ML2019 (c.170). Modified from a division of Cea2016 (c.125), Cea2019 (c.125), Pea2017 (c.328).

Greererpeton (Smithson, 1981), *Diploceraspis* (Beerbower, 1963) and most microsaurs (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2021) have a toothrow of teeth clearly larger than any surrounding denticles, and comparable to the marginal teeth, on the anterior coronoid.

ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 0), Recumbirostra (0 -> 1). DELTRAN: Tetrapoda (1 -> 0), *Diploceraspis sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1).

275. Tooth row on middle coronoid: absent (0); present (1); middle coronoid absent (inapplicable).

Rea2003 (c.209), RC2007 (c.219), ML2019 (c.174). Modified from a division of Cea2016 (c.125), Cea2019 (c.125), Pea2017 (c.328).

A toothrow on the middle coronoid is noted in the outgroup (Clack & Finney, 2005; Rawson et al., 2021), and the microsaurs *Pantylus* (Carroll & Gaskill, 1978) and *Euryodus* (Gee et al., 2021).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0). ACCTRAN: *Recumbirostra*(0 -> 1). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1).

276. Tooth row on posterior coronoid: absent (0); present (1); posterior coronoid absent (inapplicable).

Rea2003 (c.213), RC2007 (c.223), ML2019 (c.178). Modified from a division of Cea2016 (c.125), Cea2019 (c.125), Pea2017 (c.328).

The distribution of a toothrow on the posterior coronoid is almost identical to ch.229. However, there are some differences noted, and as such these are retained as separate characters. araeoscelidians (Reisz, 1977; Reisz et al., 1984), *Captorhinus* (Fox & Bowman, 1966), some former "parareptiles" (Gow, 1972; Reisz et al., 2007) and most synapsids (Romer et al., 1940; Laurin, 1993; Bolt & Scott, 1995; Modesto, 1995) lack a tooth row on the posterior coronoid, but they lack a middle coronoid altogether. *Vaughnitis* has a tooth row on the posterior coronoid (Brocklehurst et al., 2016).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Vaughnitis smithae* (0 -> 1). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Huskerpeton englehorni* (1 -> 0). DELTRAN: *Euryodus sp.* (0 -> 1), *Pantylus cordatus* (0 -> 1).

277. Coronoid tooth size relative to marginal teeth: smaller (0); equal in size or larger (1).

A2001 (c.108), Cea2016 (c.128), Cea2019 (c.128), Hea2013 (c.138), Pea2017 (c.330).

Particularly large coronoid teeth are noted in *Pantylus* (Carroll & Gaskill, 1978) and *Diploceraspis* (Beerbower, 1963).

Unambiguous: *Pantylus cordatus* (0 -> 1). ACCTRAN: Aïstopoda (0 -> 1). DELTrAN: *Diploceraspis sp.* (0 -> 1).

278. Separately ossified angular: absent (0); present (1).

LR1997 (c.89), Lea1998 (c.85), Rea2003 (c.194), RC2007 (c.204), ML2019 (c.160).

A separately ossified angular is lost in the aïstopod *Phlegethontia* (Anderson, 2002), where the mandible is simplified to only two ossifications.

Unambiguous: *Phlegethontia linearis* (1 -> 0).

279. Angular dorsoventral depth as a proportion of dorsoventral jaw depth, at the point of deepest dorsoventral extent of angular: less deep than half of jaw (0); deeper than half of jaw (1).

A2001 (c.97), Hea2013 (c.127), Pea2017 (c.91).

The angular is measured, in lateral view, at its deepest point, compared to the dorsoventral height of the jaw at the same point. There is no obvious phylogenetic signal to this character. Taxa as disparate as stem tetrapods such as *Greererpeton* (Smithson, 1981), temnospondyls such as *Dendrerpeton* (Arbez et al., 2022), former "lepospondyls" such as the microsaur *Hapsidopareion* (Carroll & Gaskill, 1978) and crown amniotes such as *Orovenator* (Ford & Benson, 2019) possess an angular that is dorsoventrally shallower than half of the dorsoventral jaw depth. However, there are stem tetrapods such as *Baphetes* (Beaumont, 1977), temnospondyls such as *Balanerpeton* (Milner & Sequeira, 1993), crown amniotes such as most synapsids (e.g. Bolt & Scott, 1995) and the microsaur *Tuditanus* (Carroll & Gaskill, 1978) all possess a dorsoventrally deeper angular.

Unambiguous: *Diploceraspis sp.* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Euryodus sp.* (0 -> 1), *Pantylus cordatus* (0 -> 1), Neoreptilia (1 -> 0), *Balanerpeton woodi* (0 -> 1), *Baphetes sp.* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Acherontiscus caledoniae* (0 -> 1), Diadectamorpha (1 -> 0),

Orobates pabsti (0 -> 1). DELTRAN: *Adelogyrinus simorhynchus* (1 -> 0), Aïstopoda (1 -> 0), *Diadectes abistus* (1 -> 0), *Limnoscelis paludis* (1 -> 0).

280. Anteriormost extent of the angular in lateral view: posterior to mid-point of tooth row (0); in line with or anterior to mid-point of tooth row (1).

A2001 (c.105), Hea2013 (c.135), Pea2017 (c.99).

The angular extends anteriorly at least to the mid-point of the toothrow in variety of taxa, including multiple former "lepospondyls" such as *Brachydectes* (Pardo et al., 2016), *Acherontiscus* (Clack et al., 2019) and *Diploceraspis* (Beerbower, 1963), but particularly within microsaurs (Carroll & Gaskill, 1978; Gee et al., 2019). The condition is also observed in edaphosaurids (Modesto, 1995) and sphenacodontids (Romer et al., 1940; Laurin, 1993; Spindler, 2016), and the stem tetrapods *Archeria* (Holmes, 1989) and *Silvanerpeton* (Ruta & Clack, 2006).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Diploceraspis sp.* (0 -> 1), *Tuditanus punctulatus* (0 -> 1), *Hapsidopareion lepton* (0 -> 1), *Westlothiana lizziae* (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0), *Gephyrostegus bohemicus* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), Adelospondyli (0 -> 1), *Adelogyrinus simorhynchus* (1 -> 0). DELTRAN: *Acherontiscus caledoniae* (0 -> 1), *Utaherpeton franklini* (0 -> 1), *Silvanerpeton miripedes* (0 -> 1), *Archeria crassidisca* (0 -> 1).

281. Angular reaching or not reaching posteriormost extent of lower jaw: does not reach posteriormost point (0); reaches posteriormost point (1).

Rea2003 (c.197), RC2007 (c.207), Kea2014 (c.93), Cea2016 (c.116), ML2019 (c.162), Cea2019 (c.116).

In most ingroup taxa, the angular participates in the posterior margin of the mandible in lateral view, including taxa ranging as widely as *Baphetes* (Beaumont, 1977), *Seymouria* (Berman et al., 2000), *Tuditanus* (Carroll & Gaskill, 1978) and *Petrolacosaurus* (Reisz, 1977). Even when the mandible is sloping anteroventrally to posterodorsally, if the angular forms part of this margin then that is considered to be state 1, such as in *Paleothyris* (Carroll, 1969). However, in several taxa, such as former "parareptiles" (Gow, 1972; Reisz et al., 2007; Modesto et al., 2015) and *Diadectes* (Berman et al, 1998), the articular extends to the ventral margin of the jaw and prevents the angular reaching the posterior margin.

Unambiguous: Tetrapoda + *Baphetes sp.* (0 -> 1), *Hapsidopareion lepton* (1 -> 0), *Westlothiana lizziae* (1 -> 0), *Aerosaurus wellesi* (1 -> 0), Reptilia (1 -> 0), *Diadectes abistus* + *Orobates pabsti* (1 -> 0). ACCTRAN: Nectridea (1 -> 0), *Diplocaulus sp.* (0 -> 1),

Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 0). DELTRAN: *Diploceraspis sp.* (1 -> 0), *Keraterpeton galvani* (1 -> 0), Sphenacodontidae (1 -> 0).

282. Angular, cross section of posteroventral border: weakly developed ridge or keel or smooth (0), prominent, sheet-like keel forming reflected lamina (1)

283. Medially-projecting flange on dorsal edge along posterior border of adductor fossa on prearticular: absent (0); present (1).

Pea2017 (c.322).

A medial flange on the prearticular is present in anthracosaurs (Panchen, 1977; Holmes, 1989), as well as a small number of other taxa, namely *Pantylus* (Carroll & Gaskill, 1978) and *Orovenator* (Ford & Benson, 2019).

Unambiguous: *Pantylus cordatus* (0 -> 1), *Orovenator mayorum* (0 -> 1). ACCTRAN: Embolomeri + *Chroniosaurus dongusensis* (0 -> 1). DELTRAN: Embolomeri (0 -> 1).

284. Longitudinal ridge below coronoids present on prearticular: absent (0); present (1).

Cea2016 (c.150), Cea2019 (c.150), Pea2017 (c.321).

A medial ridge on the prearticular, anterior to that of ch.236 and below the coronoids, is present in *Archeria* (Holmes, 1989).

ACCTRAN: Embolomeri + *Chroniosaurus dongusensis* (0 -> 1). DELTRAN: *Archeria crassidisca* (0 -> 1).

285. Prearticular - splenial contact: absent (0); present (1).

Novel

A contact between the splenial and prearticular is almost ubiquitous across the taxa included in this analysis, but is absent in a small number of taxa such a contact is absent. In *Huskerpeton* (Huttenlocker et al, 2013), for example the coronoid series is present between them, preventing contact. An absence of a contact between the splenial and prearticular is also observed in *Llistrofus* (Gee et al., 2019), *Anthracosaurus* (Panchen, 1977) and *Belebey* (Reisz et al., 2007).

Unambiguous: *Huskerpeton englehorni* (1 -> 0), *Llistrofus pricei* (1 -> 0), *Anthracosaurus russelli* (1 -> 0). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0). DELTRAN: *Belebey vegrandis* (1 -> 0).

286. Prearticular - surangular contact: absent (0); present (1).

Novel

Unambiguous: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0), Diadectamorpha (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), Adelospondyli (1 -> 0), *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), *Balanerpeton woodi* (1 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Acherontiscus caledoniae* (1 -> 0), *Lethiscus* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1).

287. Denticle shagreen on prearticular: absent (0); present (1).

Modified from a division of Cea2016 (c.148), Cea2019 (c.148), Pea2017 (c.339).

A denticle shagreen on the prearticular is present only in stem tetrapods such as *Whatcheeria* (Rawson et al, 2021) *Westlothiana*, and *Caerorachis* (Ruta et al., 2001) and uniquely in *Edaphosaurus* among crown tetrapods (Modesto, 1995).

Unambiguous: *Westlothiana lizziae* (0 -> 1), *Caerorachis bairdi* (0 -> 1), *Whatcheeria deltae* (0 -> 1). ACCTRAN: Edaphosauridae (0 -> 1). DELTRAN: *Edaphosaurus boanerges* (0 -> 1).

288. Ceratobranchials in adults: absent or unossified (0) present and ossified (1).

Modified from Mea2024 (c80).

Unambiguous: Embolomeri (1 → 0), Aistopoda (1 to 0), *Pantylus* (0 to 1), *Brachydectes* (0 to 1), *Dendrerpeton* (0 → 1).

289. Ceratobranchials, external surface: groove or canal, presumably for branchial artery (0), external surface smooth, featureless (1).

This study, based on the review on the branchial apparatus of tetrapods by Witzmann (2013).

The ceratobranchials of temnospondyls and stem tetrapods (e.g., *Acanthostega* or adelospondylids, Witzmann 2013) bears a groove for the branchial artery, indicating that the ceratobranchials acted as a gill for gas exchange. This morphology is present in *Westlothiana*. In contrast, the ossified certabranchials of total-group amniotes lack such a groove (e.g., the molgophid *Brachydectes* (Wellstead 1991).

Unambiguous: Reptiliomorpha (0 to 1).

290. Ossified basibranchial in adults, absent (0), present (1).

Modified from Mea2024 (c81).

Unambiguous: Reptiliomorpha (1 to 0), Temnospondyli including Nectridea (0 to 1).

291. Ossified hypobranchials in adults: absent (0), present (1).

Based on from Mea2024 (c80,81).

Unambiguous: Reptiliomorpha (1 to 0), *Brachydectes* (0 to 1).

292. Separately ossified proatles: absent (0); present (1).

A2001 (c.139), Hea2013 (c.174), Pea2017 (c.136).

ACCTRAN: Aïstopoda (1 -> 0), Aïstopoda (0 -> 1). DELTRAN: *Adelogyrinus simorhynchus* (1 -> 0), *Microbrachis pelikani* (1 -> 0).

293. Articulation of atlantal neural arch to atlantal centrum: sutured (0); indistinguishably fused (1).

LR1997 (c.108), Lea1998 (c.104), A2001 (c.137), Rea2003 (c.284), RC2007 (c.302), Cea2016 (c.199), ML2019 (c.251), Cea2019 (c.199), Hea2013 (c.172), Pea2017 (c.134).

In most former "lepospondyls", there is no visible trace of a suture between the atlantal centrum and atlantal neural arch, including aïstopods (Carroll, 1998; Anderson, 2002), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and most microsaurs (Carroll & Gaskill, 1978; Gee et al., 2021). This condition is also observed in *Doleserpeton* (Sigurdsen & Bolt, 2010), protorothyridids (Carroll, 1964; 1969), araeoscelidians (Reisz, 1977; Langston & Reisz, 1981), and *Diadectes* (Berman et al., 1998),

Unambiguous: *Tuditanus punctulatus* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Diadectes abistus* (0 -> 1). ACCTRAN: Aïstopoda (0 -> 1), *Brachydectes newberryi* (1 -> 0), Synapsida (0 -> 1), Edaphosauridae + Sphenacodontia (1 -> 0), Temnospondyli (0 -> 1). DELTRAN: Nectridea (0 -> 1), Aïstopoda (0 -> 1), *Aerosaurus wellesi* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

294. Atlantal neural arch halves: paired, sutured to each other (0); fused into single arch (1).

A2001 (c.135), Hea2013 (c.170), Pea2017 (c.132).

In the stem tetrapod *Greererpeton* (Smithson, 1981), the atlantal neural arch consists of two laterally paired ossifications that suture along the midline, a condition that is present across almost all included taxa. In most former "lepospondyls", however, the two lateral halves of the neural arch are indistinguishably fused with no visible trace of a suture, including *Adelogyrinus* (Andrews & Carroll, 1991), the aïstopod *Phlegethontia* (Anderson, 2002), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018), and the microsaur *Cardiocephalus* (Carroll & Gaskill, 1978). The condition is also present in *Seymouria* (Berman et al., 2000) and *Caerorachis* (Ruta et al., 2001).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Cardiocephalus sp.* (0 -> 1), *Seymouria sanjuanensis* (0 -> 1), *Caerorachis bairdi* (0 -> 1).

295. Atlas parapophyses: absent (0); present (1).

Modified from a division of A2001 (c.136), Hea2013 (c.171), Pea2017 (c.133).

ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Microbrachis pelikani* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), Neoreptilia (1 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Aïstopoda (1 -> 0), *Hapsidopareion lepton* (1 -> 0), *Westlothiana lizziae* (1 -> 0), *Milleropsis pricei* (1 -> 0).

296. Atlas parapophyses position: on centrum (0); on transverse process (1); absent (inapplicable).

Modified from a division of A2001 (c.136), Hea2013 (c.171), Pea2017 (c.133).

ACCTRAN: *Diadectes abistus* + *Orobates pabsti* (1 -> 0). DELTRAN: *Orobates pabsti* (1 -> 0).

297. Articulation of axial neural arch to axial centrum: sutured (0); indistinguishably fused (1).

Rea2003 (c.285), RC2007 (c.303), ML2019 (c.252).

In stem tetrapods, the axis arch and centrum are joined with a visible suture between them, such as in *Greererpeton* (Smithson, 1981) and *Westlothiana*. Fusion between the arch and the centrum of the axis, thus erasing any visible trace of a suture, is present in aïstopods (Carroll, 1998; Anderson, 2002), the temnospondyl *Balanerpeton* (Milner & Sequeira, 1993), *Captorhinus* (Fox & Bowman, 1966), protorothyridids (Carroll, 1964; 1969), araeoscelidians (Reisz, 1977; Langston & Reisz, 1981), some synapsids (Romer et al., 1940; Laurin, 1993;

Campione & Reisz, 2010), *Orovenator* (Ford & Benson, 2019), diadectamorphs (Romer, 1946; Berman et al., 1998; 2004), nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and some microsaurs (Carroll & Gaskill, 1978; Gee et al., 2021).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0). ACCTRAN: Aïstopoda (0 -> 1), *Brachydectes newberryi* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (0 -> 1), *Pantylus cordatus* (1 -> 0), Neoreptilia (1 -> 0), Temnospondyli (0 -> 1). DELTRAN: Nectridea (0 -> 1), Aïstopoda (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* (0 -> 1), *Micraroter erythrogeois* (0 -> 1), *Milleropsis pricei* (1 -> 0), *Balanerpeton woodi* (0 -> 1).

298. Axial neural arch anteroposterior length relative to more posterior neural arches: anteroposteriorly shorter than more posterior arches (0); equal in size to more posterior arches (1); anteroposteriorly longer than posterior arches (2). (ordered).

Hea2013 (c.175), Pea2017 (c.137).

In some taxa, the axial neural arch is expanded anteroposteriorly in length, so that is is clearly and distinctly longer along its anteroposterior axis than the arches immediately posterior to it. This condition is observed in the diadectamorph *Orobates* (Berman et al., 2004) and almost all total-group amniotes crownwards of diadectamorphs, including *Captorhinus* (Fox & Bowman, 1966), protorothyridids (Carroll, 1964; 1969), araeoscelidians (Reisz, 1977; Langston & Reisz, 1981), reptiles (Gow, 1972; 1974; Reisz et al., 1984; Ford & Benson, 2019) and most synapsids included in this analysis (e.g. Romer et al., 1940; Bolt & Scott, 1995; Modesto, 1995) with the exception of *Eocasea* (Reisz & Fröbisch, 2014) and *Varanops* (Campione & Reisz, 2010). The condition is also observed in *Greererpeton* (Smithson, 1981), *Balanerpeton* (Milner & Sequiera, 1993), *Gephyrostegus* (Klembara et al., 2014), *Seymouria* (Berman et al., 2000), *Diplocaulus* (Douthitt, 1917) and a small number of microsaurs (Carroll & Gaskill, 1978).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 2), *Euryodus sp.* (1 -> 2), *Varanops brevirostris* (2 -> 0), *Diadectes abistus* (2 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (2 -> 1), Embolomeri + *Chroniosaurus dongusensis* (2 -> 0). ACCTRAN: *Diplocaulus sp.* + *Diploceraspis sp.* (1 -> 2), *Microbrachis pelikani* (1 -> 2), Caseasauria (2 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (2 -> 1). DELTRAN: *Diplocaulus sp.* (1 -> 2), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* (2 -> 1), *Eocasea martini* (2 -> 0), *Doleserpeton annectens* (2 -> 1).

299. Anterior articulating surface of atlas: equal in diameter to posterior articulating surface (0); laterally expanded relative to posterior articulating surface (1).

Hea2013 (c.168), Pea2017 (c.130), LR1997 (c.110), Lea1998 (c.106), A2001 (c.133).

In microsaurs, the atlantal intercentrum has a somewhat trapezium-like shape in ventral view. The centrum expands towards the anterior end, so that the anterior surface approaches twice as wide, laterally, as the posterior surface (Carroll & Gaskill, 1978; Huttenlocker et al., 2013; Gee et al., 2019). A similar condition is also observed in *Diplocaulus* (Douthitt, 1917).

Unambiguous: *Diplocaulus sp.* (0 -> 1).

300. Odontoid process on atlas: absent (0); present (1).

RC2007 (c.304), ML2019 (c.253), Cea2019 (c.217). Modified from a division of LR1997 (c.109), Lea1998 (c.105).

An odontoid process on the atlas describes an anteriorly protruding, stout process of the atlas body fitting into a variously deep recess or pit in the occiput (Anderson, 2001; Ruta & Coates, 2007). It is present in most former "lepospondyls" (Carroll & Gaskill, 1978; Andrews & Carroll, 1991; Carroll, 1998; Anderson, 2002; Anderson et al., 2003; Huttenlocker et al., 2013) apart from nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018), and in *Gerobatrachus* (Anderson et al, 2008).

Unambiguous: Nectridea (1 -> 0), *Gerobatrachus hottoni* (0 -> 1).

301. Cervical vertebrae, ventral surface of cervical centra: rounded (0); bearing a low keel or ridge (1), bearing a prominent, transversely narrow, sheet-like keel (2). (ordered).

FB2020 (c207). Modified from Gea1988 (c.139), L1991 (c.H2), Rea1992 (c.69), L1993 (c.92), DR1997 (c.103), Rea2010 (c.70), N2011 (c.190), B2012 (c.154), Pea2015 (c.108), E2016 (c.327), Sea2018 (c.109).

The size and shape of the ventral keel varies between various clades of crown amniotes. State 1, a low keep or ridge, is present in *Haptodus* (Laurin 1993), varanopids (Langston & Reisz, 1981; Campione & Reisz, 2010) and captorhinids (Fox & Bowman, 1966). It is also present in *Orovenator* (Ford & Benson, 2019) and araeoscelidians (Reisz, 1977; Reisz et al., 1984). Derived sphenacodontids possess a dorsoventrally deeper and sheet-like keel (state 2, Romer et al., 1940), while in caseids there is no keel, and they possess a rounded ventral surface (state 0)(Olson et al., 1968; Reisz & Fröbisch, 2014).

Unambiguous: Aïstopoda (1 -> 0), *Diplocaulus sp.* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), Caseasauria (1 -> 0), Sphenacodontidae + *Pantelosaurus saxonicus* (1 -> 2), *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (1 -> 0), Diadectamorpha (1 -> 0). DELTRAN:

Hylonomus lyelli + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), *Eocasea martini* (1 -> 0), *Dimetrodon sp.* (1 -> 2), *Youngina capensis* (1 -> 0).

302. Separately ossified atlantal intercentrum: absent (0); present (1).

LR1997 (c.113), Lea1998 (c.109), A2001 (c.116), Hea2013 (c.167), Pea2017 (c.129).

In many former "lepospondyls", the intercentrum is entirely lost (ch.267) (Douthitt, 1917; Beerbower, 1963; Carroll & Gaskill, 1978; Andrews & Carroll, 1991; Carroll et al., 1991; Carroll; 1998; Anderson, 2002; Anderson et al., 2003; Huttenlocker et al., 2013; Pardo et al., 2016; Milner & Ruta, 2009; Clack et al., 2019; Gee et al., 2019). This includes the atlantal intercentrum. *Westlothiana* retains intercentra in the trunk and cervical region, including the atlas. An atlantal intercentrum is also lost in the temnospondyl *Doleserpeton* (Sigurdsen & Bolt, 2010) and the synapsid *Echinerpeton* (Mann & Paterson, 2020).

Unambiguous: *Echinerpeton intermedium* (1 -> 0). ACCTRAN: Temnospondyli (1 -> 0). DELTRAN: *Doleserpeton annectens* (1 -> 0).

303. Cervical ribs expanded distally: absent (0), present (1).

Modified from Sea2022 (c.264), J2025(c. 460).

Unambigous: *Greererpeton burkemorani* (1 to 0). DELTRAN: *Amniota* + *Protorothyrididae* (1 to 0), *Limnoscelis paludis* (1 to 0). ACCTRAN: Amniota + Protorothyrididae (1 to 0), Diadectomorpha (1 to 0).

304. Elements making up trunk vertebrae: intercentrum absent, pleurocentrum is only element (0); intercentrum present but pleurocentrum is dominant element (1); intercentrum and pleurocentrum make roughly equal contribution to centrum (2); intercentrum is dominant (3). (ordered).

Modified from A2001 (c.115), Cea2016 (c.171), Cea2019 (c.171), Hea2013 (c.148), Lea1998 (c.98), LR1997 (c.102), ML2019 (c.259), Pea2017 (c.110), RC2007 (c.316), Rea2003 (c.299).

A variety of conditions of the elements making up centra appears across tetrapods (Danto et al, 2012). In most stem tetrapods, temnospondyls, and *Gerobatrachus* the rachitomous condition is present where the intercentrum is the dominant element (state 3)(Romer & Witter, 1942; Smithson, 1981; Milner & Sequeira, 1993; Clack & Finney, 2005; Anderson et al., 2008; Sigurdsen & Bolt, 2010; Rawson et al., 2021; Arbez et al., 2022). Embolomeres, so named for their embolomerous centra, possess an intercentrum and pleurocentrum that are roughly equivalent in size (Holmes, 1989). In most amniotes and *Silvanerpeton* (Ruta & Clack, 2006), the pleurocentrum is the dominant element, and they retain a small, wedge shaped intercentrum, including seymouriamorphs, diadectamorphs, protorothyridids,

captorhinids and crown amniotes (e.g. Romer et al., 1940; Romer, 1946; Fox & Bowman, 1966; Carroll, 1969; Gow, 1972; Reisz et al., 1984; Berman et al., 2000; 2004), a condition which is also present in *Westlothiana*. However, in derived caseasaurs, intercentra are almost completely lost (Olson et al., 1968; Brocklehurst et al., 2016). This is state 0, the 'lepospondylous' condition, and is present in former "lepospondyls" as well (Carroll & Gaskill, 1978; Andrews & Carroll, 1991; Wellstead, 1991; Carroll, 1998; Anderson, 2002; Anderson et al., 2003; Milner & Ruta, 2009; Milner, 2018). However, in a small number of microsaurs, such as *Euryodus* and *Cardiocephalus*, a small number of trunk intercentra are retained, although they occupy a more superficial position relative to the pleurocentra than in other taxa, and are positioned more distally relative to the pleurocentra (Carroll & Gaskill, 1978).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (3 -> 1), *Acherontiscus caledoniae* (0 -> 2), *Casea broilii* (1 -> 0), *Vaughnitis smithae* (1 -> 0), *Procynosuchus delaharpeae* (1 -> 0). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (1 -> 2). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* (0 -> 1), *Archeria crassidisca* (1 -> 2).

305. Capitular facets on posterior rim of mid trunk centra: absent (0); present (1).

Rea2003 (c.311), RC2007 (c.328), ML2019 (c.271).

Capitular facets on the posterior rim of the mid trunk vertebrae are found in a small number of former "lepospondyls" including *Adelogyrinus* (Andrews & Carroll, 1991), *Brachydectes* (Wellstead, 1991), *Scincosaurus* (but not other supposed Nectrideans, Milner & Ruta, 2009) and *Microbrachis* (Carroll & Gaskill, 1978).

Unambiguous: *Microbrachis pelikani* (0 -> 1). ACCTRAN: Adelospondyli (0 -> 1), Diplocaulidae (1 -> 0). DELTRAN: *Adelogyrinus simorhynchus* (0 -> 1), *Brachydectes newberryi* (0 -> 1), *Scincosaurus crassus* (0 -> 1).

306. Number of presacrals: <20 (0); 20-24 (1); 25-35 (2); >35 (3). (ordered).

LR1997 (c.118), Lea1998 (c.114), A2001 (c.180), Hea2013 (c.145), Pea2017 (c.107).

The division of states across this taxa is consistent with the previous analyses of Anderson (2001), Huttenlocker et al. (2013) and Pardo et al. (2017) which include similar taxon samples to the taxa of focus in this analyses. Anderson (2001) suggested that above and below 35 as a top cut off was intended to capture general elongation while avoiding the issue of limbless ecomorph long branch attraction. Many synapsids are characterised by 27 vertebrae (Romer et al., 1940; Modesto, 1995; Campione & Reisz, 2010; Reisz & Fröbisch, 2014; Mann & Paterson, 2020), and a similar number, ranging from around 24 to 27 is

widespread across crownward stem and early crown amniotes including in *Hylonomus* (26 vertebrae, Carroll, 1964), *Petrolacosaurus* (26 vertebrae, Reisz, 2918), *Captorhinus* (27 vertebrae, Fox & Bowman, 1966) and in reptiles (Now, 1972; 1974; Modesto et al., 2015). former "lepospondyls" show a great variety of presacral number, from fewer than 18 in *Diplocaulus* (Douthitt, 1917) to at least 69 in *Brachydectes* (Wellstead, 1991).

Unambiguous: *Microbrachis pelikani* (2 -> 3), *Casea broilii* (2 -> 1), *Diadectes abistus* (2 -> 1), Seymouriamorpha + *Gephyrostegus bohemicus* (2 -> 1), *Gerobatrachus hottoni* (1 -> 0), *Greererpeton burkemorani* (2 -> 3). ACCTRAN: Aïstopoda (3to2), Aïstopoda (2 -> 3), Nectridea (3 -> 0), *Scincosaurus crassus* (0 -> 1), *Pantylus cordatus* (3 -> 1), Neoreptilia (2 -> 1), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (1 -> 2), Embolomeri (2 -> 3), Temnospondyli (2 -> 1). DELTRAN: Aïstopoda (2 -> 3), Diplocaulidae (3 -> 0), *Scincosaurus crassus* (3 -> 1), *Cardiocephalus sp.* (2 -> 3), *Pantylus cordatus* (2 -> 1), *Westlothiana lizziae* (2 -> 3), *Youngina capensis* (2 -> 1), *Milleropsis pricei* (2 -> 1), *Archeria crassidisca* (2 -> 3), Temnospondyli except *Edops craigi* (2 -> 1).

307. Number of sacral vertebrae: none (0); one (1); two (2); three (3). (ordered).

LR1997 (c.119), Lea1998 (c.115), A2001 (c.145), Hea2013 (c.181), Pea2017 (c.143).

Unambiguous: Amniota + Diadectamorpha + Microsauria (1 -> 2), *Seymouria sanjuanensis* (1 -> 2). ACCTRAN: Adelospondyli (1 -> 2), Synapsida (2 -> 3), *Varanops brevirostris* (3to2), *Eocasea martini* (3to2), *Belebey vegrandis* + *Erpetonyx arsenaultorum* (2 -> 3). DELTRAN: *Utaherpeton franklini* (1 -> 2), *Aerosaurus wellesi* (2 -> 3), *Casea broilii* (2 -> 3), Edaphosauridae + Sphenacodontia (2 -> 3), *Erpetonyx arsenaultorum* (2 -> 3).

308. Accessory articulations above zygapophyses present in at least some trunk and caudal vertebrae: absent (0); present (1).

A2001 (c.112), Rea2003 (c.286), RC2007 (c.305), ML2019 (c.254), Cea2019 (c.218).

State 1 of this character describes interdigitating projections of neural arches dorsal to the zygapophyses. Such accessory articulations are present in nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and the aïstopod *Oestocephalus* (Carroll, 1998).

Unambiguous: Nectridea (0 -> 1), *Oestocephalus sp.* (0 -> 1), *Youngina capensis* (0 -> 1).

309. Supraneural caudal (or 'tail fin') skeleton: absent (0), present (1)

Modified from P2024 (c375).

Unambiguous: Whatcheeridae (1 to 0), *Westlothiana* + aistopods + Tetrapoda (1 to 0). ACCTRAN: Total-group tetrapods more derived than Embolomeri (1 to 0).

310. Haemal arches: absent (0); present (1).

A2001 (c.123), Hea2013 (c.156), Pea2017 (c.118).

Hemal arches are observed to be absent in aïstopods (Carroll, 1998; Anderson, 2002) and the microsaur *Tuditanus* (Carroll & Gaskill, 1978). However, they are unknown in many other taxa as they are often lost during preservation.

Unambiguous: Aïstopoda (1 -> 0), *Tuditanus punctulatus* (1 -> 0).

311. Articulation of haemal arches to caudal centra: loosely articulated or sutured (0); fused (1); haemal arches absent (inapplicable).

A2001 (c.124), Rea2003 (c.289), RC2007 (c.308), ML2019 (c.257), Hea2013 (c.157), Pea2017 (c.119).

Haemal arches are fused to the caudal centra in nectrideans (Douthitt, 1917; Beerbower, 1963; Milner, 2018), a feature which is characteristic of the robustly ossified tails of the clade (Ruta et al., 2003). The condition is also observed here in derived temnospondyl *Doleserpeton* (Sigurdsen & Bolt, 2010).

ACCTRAN: Nectridea (0 -> 1), Temnospondyli (0 -> 1). DELTRAN: Diplocaulidae (0 -> 1), *Doleserpeton annectens* (0 -> 1).

312. Haemal arch size: shorter than neural spines on same vertebrae (0); equal or longer than neural spines on same vertebrae (1).

A2001 (c.125), Hea2013 (c.158), Pea2017 (c.120).

Small neural spines in the tail are noted in a small number of taxa, including the amniotes *Eocasea* (Reisz & Fröbisch, 2014) and *Archaeovenator* (Reisz & Dilkes, 2003) and the stem amniote *Caerorachis* (Ruta et al, 2001).

Unambiguous: *Eocasea martini* (1 -> 0), *Caerorachis bairdi* (1 -> 0). ACCTRAN: Reptilia (1 -> 0). DELTRAN: *Archaeovenator hamiltonensis* (1 -> 0).

313. Haemal arch shape: non-parallel (triangular) (0); parallel (rectangular) (1).

A2001 (c.127), Hea2013 (c.160), Pea2017 (c.122).

Parallel-sided, rectangularly shaped haemal arches are present in some former microsaurs including *Brachydectes* (Pardo et al., 2016) and *Pantylus* (Carroll & Gaskill, 1978). This morphology is also present in derived nectrideans where they form a robust, rectangular shape contributing to the well ossified nature of the nectridean tail (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009; Milner, 2018) and derived temnospondyls such as *Doleserpeton* (Sigurdsen & Bolt, 2010) are also noted to have haemal arches of this shape.

ACCTRAN: *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). DELTRAN: *Doleserpeton annectens* (0 -> 1).

314. Rib curvature: ribs straight (0); ribs curved in at least part of the trunk (1).

LR1997 (c.120), Rea2003 (c.280), RC2007 (c.297), Cea2016 (c.203), ML2019 (c.246), Cea2019 (c.203), Hea2013 (c.179), Pea2017 (c.141).

Straight ribs are present in the stem tetrapods *Pederpes* (Clack & Finney, 2005) and *Baphetes* (Beaumont, 1977) as well aistopods such as *Lethiscus* (Pardo et al., 2017), temnospondyls and *Gerobatrachus* (Milner & Sequeira, 1993; Anderson et al., 2008; Sigurdsen & Bolt, 2010; Arbez et al., 2022) and the seymouriamorphs *Discosauriscus* (UMZC2000.11; Klembara, 1997) and *Ariekanerpeton* (Klembara & Ruta, 2005). As such, this condition is present in stem tetrapods, and both temnospondyls and amniotes, indicating that curved ribs were independently evolved on at least several occasions.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Lethiscus stocki* (1 -> 0), *Limnoscelis paludis* (1 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0), *Greererpeton burkemorani* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

315. Costal process at head of rib giving rib distinctive “k-shape”: absent (0); present (1).

Cea2019 (c.237), Hea2013 (c.180), Pea2017 (c.142), A2001 (c.144), RC2007 (c.295).

This process, found in aïstopods (Carroll, 1998; Anderson, 2002; Pardo et al., 2017), gives the rib head a distinctive “k-shape”.

Unambiguous: Aïstopoda (0 -> 1).

316. Length of longest trunk ribs: less than two and a half times the maximum height of neural arch plus centrum of largest trunk vertebrae (0); more than two and a half times this height (1).

Lea1998 (c.116), Cea2016 (c.204), ML2019 (c.250), Cea2019 (c.204), Hea2013 (c.178), Pea2017 (c.140).

This character applies to the longest ribs in the spine. Measured vertebrae and ribs were chosen from the same section of trunk.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Discosauriscus austriacus* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), *Brachydectes newberryi* (0 -> 1), *Diplocaulus sp.* + *Diploceraspis sp.* (0 -> 1). DELTRAN: *Keraterpeton galvani* (1 -> 0), *Scincosaurus crassus* (1 -> 0), Aïstopoda (1 -> 0).

317. Number of sacral rib pairs: none (0); one (1); two or more (2). (ordered).

Novel

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Solenodonsaurus janenschi* (2 -> 1), *Ariekanerpeton sigalovi* (2 -> 1), *Gephyrostegus bohemicus* (2 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 2), Embolomeri + *Chroniosaurus dongusensis* (2 -> 0). DELTRAN: Tetrapoda (1 -> 2), *Archeria crassidisca* (2 -> 0).

318. Morphology of first sacral rib: subequal to or only slightly larger than the second sacral rib (0); greatly enlarged in comparison with the second sacral rib (1).

FB2020 (c228). Modified from Bea1995 (c.76), Mea2008 (c.76, c.77), RD2003 (c.48), Mea2006 (c.53), Rea2009 (c.63), B2012 (c.173), E2016 (c.372), Sea2018 (c.122).

A greatly enlarged first sacral rib is present in some seymouriamorphs (Berman et al., 2000) and diadectamorphs (Kennedy, 2010), as well as captorhinids (Fox & Bowman, 1966) and araeoscelidians (Reisz et al., 1984). It is also present in some synapsids including varanopids (Langston & Reisz, 1981; Campione & Reisz, 2010), *Varanosaurus* (Bolt & Scott) & *Eocasea* (Reisz & Fröbisch, 2014) and is also present in *Youngina* (Gow, 1974). It is absent, however, in former "parareptiles" (Modesto et al., 2015) and *Archaeovenator* (Reisz & Dilkes, 2003).

Unambiguous: *Casea broilii* (1 -> 0), Edaphosauridae + Sphenacodontia (1 -> 0). ACCTRAN: Reptilia (1 -> 0), *Youngina capensis* (0 -> 1). DELTRAN: *Archaeovenator hamiltonensis* (1 -> 0), *Erpetonyx arsenaultorum* (1 -> 0), *Paleothyris acadiana* (1 -> 0).

319. Number of pairs of caudal ribs: two or fewer (0); three (1); four (2); five or more (3). (ordered).

A2001 (c.147), Hea2013 (c.183), Pea2017 (c.145).

Unambiguous: *Hyloplesion longicostatum* (3 -> 1), *Microbrachis pelikani* (3 -> 2), *Araeoscelis gracilis* (3 -> 0), *Seymouria sanjuanensis* (3 -> 2), *Caerorachis bairdi* (3to2). ACCTRAN: Reptilia (3to2), Captorhinidae (3 -> 1), *Diadectes abistus* + *Orobates pabsti* (3 -> 1), Embolomeri + *Chroniosaurus dongusensis* (3 -> 0), *Chroniosaurus dongusensis* (0 -> 1). DELTRAN: *Erpetonyx arsenaultorum* (3 -> 2), *Captorhinus aguti* (3 -> 1), *Orobates pabsti* (3 -> 1), *Archeria crassidisca* (3 -> 0), *Chroniosaurus dongusensis* (3 -> 1).

320. Gastralia: absent (0); present (1).

Modified from Cea2016 (c.211), Cea2019 (c.211).

Unambiguous: Aïstopoda (0 -> 1), *Araeoscelis gracilis* (1 -> 0), *Whatcheeria deltae* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0), Embolomeri + *Chroniosaurus dongusensis* (1 -> 0). DELTRAN: *Eocasea martini* (1 -> 0), Diadectamorpha (1 -> 0), *Archeria crassidisca* (1 -> 0).

321. Gastralia, if present, morphology: rectilinear scales (0), rod-like bones (1).

Modified from J2025 (c401).

Unambiguous: *Hylonomus* + Diadectomorpha + Protorothyrididae + Captorhinidae + Amniota (0 to 1), Cthonosauria + Nastrondormes (0 → 1).

322. Dorsal scales: absent (0), present but small, superficial (1) present and thick, sometimes multiple layers deep (2). (ordered).

Modified from Pea2017 (c260).

The presence of thick dorsal scales covering the body is a primitive feature for Tetrapoda and widespread among early tetrapodomorphs, including *Westlothiana* (State 2). In some crown tetrapods such as temnospondyls and recumbirostran microsaurs, small, thin scales lacking any ornamentation are present (Carroll 1968), which are sometimes restricted to the pectoral or cervical regions.

Unambiguous: Tetrapoda (2 → 0), Microsauria (0 to 1).

323. Tail length: shorter than trunk (0); at least as long as trunk (1).

Hea2013 (c.162), Pea2017 (c.124).

Some taxa, such as nectrideans and some aïstopods, are characterised by particularly long tails relative to the trunks.

Unambiguous: Nectridea (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1). ACCTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1). DELTRAN: *Phlegethontia* (0 -> 1), *Discosauriscus* (0 -> 1).

324. Separately ossified clavicle: absent (0); present (1).

LR1997 (c.125), Lea1998 (c.121).

A separately ossified clavicle is absent in aïstopods (Carroll, 1998; Anderson, 2002; Anderson et al., 2003), in which the entire appendicular skeleton is absent.

Unambiguous: Aïstopoda (1 -> 0).

325. Clavicles meet anteriorly: absent, clavicles are separate anteriorly (0); clavicles contact (1).

Rea2003 (c.228), RC2007 (c.239), Cea2016 (c.176), ML2019 (c.194), Cea2019 (c.176), A2001 (c.156), Hea2013 (c.195), Pea2017 (c.157).

In state 0, the anteroventral plates of the clavicles fail to contact each other and a strip of the ventral side of the interclavicle is interposed between them. On both sides of this strip, the impressions of the clavicular plates are discernible and the morphology of the interclavicle provides clues to the degree of separation between them. This condition is present in the stem tetrapod Pederpes (Clack & Finney, 2005), in *Adelogyrinus* (Andrews & Carroll, 1991), some temnospondyls (Sigurdsen & Bolt, 2010; Arbez et al., 2022), *Silvanerpeton* (UMZC T.1317; Ruta & Clack, 2006) and amniotes crownwards of former "lepospondyls" (e.g. Romer et al., 1940; Olson et al., 1968; Reisz et al., 1984; Reisz & Dilkes, 2003). In state 1, however, the clavicles make a contact along the midline.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Greererpeton burkemorani* (0 -> 1), *Whatcheeria deltae* (0 -> 1). ACCTRAN: Adelospondyli (1 -> 0), *Adelogyrinus simorhynchus* (1 -> 0).

326. Interclavicle, fimbriation: absent (0), present (1)

Modified Pea2017 (c151).

ACCTTRAN: Microsauria + *Hylonomus* + Diadectomorpha + Captorhinidae +Amniota (1 to 0), Microbrachomorpha (0 to 1).

327. Interclavicle, position of articulation with clavicle relative to first cervical vertebrae or occiput: level with or anterior (0), posterior (1).

Modified from J2025a (c721).

Unambiguous: *Westlothiana* + Aistopoda + Tetrapoda (0 → 1).

328. Posterior stem on interclavicle: absent (0); present (1); interclavicle absent (inapplicable).

LR1997 (c.124), Lea1998 (c.120), Rea2003 (c.229). Modified from a division of RC2007 (c.240), A2001 (c.148), Pea2017 (c.354).

A posterior stem on the interclavicle, an anteroposteriorly elongate section of bone distinctly and clearly projecting posteriorly from the interclavicle plate, is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021). It is retained widely across the included taxa, but it is absent in some other stem tetrapods (Beaumont, 1977; Smithson, 1981), temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022) and Nectrideans (Douthitt, 1917; Beerbower, 1963; Milner & Ruta, 2009).

Unambiguous: *Keraterpeton galvani* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha(0 -> 1), DELTRAN: Temnospondyli except *Edops craigi* (1 -> 0), *Greererpeton burkemorani* (1 -> 0).

329. Interclavicle posterior stem morphology: tapering along most of length (0); parallel sided along most of length, tapering abruptly towards the posterior end (1); interclavicle absent or lacking posterior stem (inapplicable).

RC2007 (c.240), Cea2019 (c.197), ML2019 (c.195), Cea2016 (c.197), Rea2003 (c.230).

In *Whatcheeria*, the posterior stem of the interclavicle is approximately parallel sided, and tapers to a point only at the posterior end, forming a blunt, rounded tip. In *Silvanerpeton* (Ruta & Clack, 2006) and seymouriamorphs (Klembara, 1997; Berman et al., 2000) the posterior stem tapers along almost its entire length, resulting in a slight but clear triangular shape to the stem. A tapering posterior stem such as this is also present in microsaurs (Carroll & Gaskill, 1978), and some crownward stem and early crown amniotes such as *Paleothyris* (Carroll, 1969), *Aerosaurus* (Langston & Reisz, 1981), *Archaeovenator* (Reisz & Dilkes, 2003) and *Milleretta* (Gow, 1972).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (0 -> 1), Reptilia (1 -> 0), *Paleothyris acadiana* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Varanopidae (1 -> 0). DELTRAN: *Aerosaurus wellesi* (1 -> 0), *Whatcheeria deltae* (0 -> 1).

330. Interclavicle plate morphology anteroposterior length to transverse with ratio: longer than wide (0); wider than long (1).

Rea2003 (c.231), ML2019 (c.196), RC2007 (c.241).

Where a posterior stem of the interclavicle is present, the anteroposterior length of the interclavicle is measured from the anteriormost extremity to where the posterolateral margins are deflected medially towards the posterior stem. Seymouriamorphs (Berman et al., 2000; Klembara & Ruta, 2005), most microsaurs (Carroll & Gaskill, 1978), and stem and crown amniotes crownwards of former "lepospondyls" possess a transversely wide interclavicle plate, including *Paleothyris* (Carroll, 1969), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), *Araeoscelis* (Reisz et al., 1984), most synapsids (e.g. Romer et al., 1940; Olson et al., 1968; Mann & Paterson, 2020), *Archaeovenator* (Reisz & Dilkes, 2003), former "parareptiles" (Gow, 1972; Modesto et al., 2015) and *Youngina* (Gow, 1974). An interclavicular plate that is anteroposteriorly longer than it is transversely wide, however, is present in non-microsaur former "lepospondyls" such as adelospondyls (Andrews & Carroll, 1991; Clack et al., 2019) and nectrideans (Beerbower, 1963; Milner, 2018) and temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022).

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Haptodus garnettensis* (1 -> 0), *Whatcheeria deltae* (0 -> 1).

331. Caudal part of interclavicle anteroposterior length relative to cranial part length: caudal part anteroposteriorly shorter (0); cranial part anteroposteriorly shorter (1).

Rea2003 (c.232), RC2007 (c.242), ML2019 (c.197).

The boundary between the two parts is measured along mediolateral line along which the interclavicle is at its greatest transverse width. Differing states exist across a variety of clades, with no large phylogenetic signal evident. For example, an anteroposteriorly longer caudal part is present in temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022) and seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005). An anteroposteriorly longer cranial part exists in taxa as disparate as *Greererpeton* (Smithson, 1981), *Silvanerpeton* (Ruta & Clack, 2006) and *Haptodus* (Laurin, 1993).

Unambiguous: Adelospondyli (1 -> 0), *Diploceraspis sp.* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0), Synapsida (0 -> 1), *Haptodus garnettensis* (1 -> 0),

Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1). DELTRAN: Caseasauria + *Echinerpeton intermedium* (0 -> 1), *Dimetrodon sp.* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (0 -> 1), *Chroniosaurus dongusensis* (0 -> 1), Temnospondyli except *Edops craigi* (0 -> 1).

332. Sternum, not mineralised (0); mineralised (1).

FB2020 (c.246), LR1995 (c.100).

This character was considered by Laurin & Reisz (1995) to be a synapomorphy of diapsid reptiles. In this taxon sample, it is noted only in *Araeoscelis* (Reisz et al, 1984) and *Youngina* (Gow, 1974). It is very difficult to score the absence of a sternum with any confidence as lack of preservation is not good evidence of the absence of mineralisation. As such, this character is scored as unknown in many taxa.

Unambiguous: *Araeoscelis gracilis* (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1). DELTRAN: *Youngina capensis* (0 -> 1).

333. Scapulocoracoid ossification: single ossification (0); divided into multiple ossifications (1).

LR1997 (c.131), Lea1998 (c.128), A2001 (c.159), Rea2003 (c.233), RC2007 (c.244), Cea2016 (c.210), ML2019 (c.199), Cea2019 (c.210), Hea2013 (c.198), Pea2017 (c.160).

In many disparate taxa from clades across the included taxa, including the stem tetrapod Pederpes (Clack & Finney, 2005) and crown amniotes *Varanops* (Campione & Reisz, 2010) and *Araeoscelis* (Reisz et al, 1984), the scapulocoracoid is fused into a single ossification with no trace of sutures.

Unambiguous: *Varanops brevirostris* (0 -> 1), *Araeoscelis gracilis* (0 -> 1), Seymouriamorpha (0 -> 1), *Pederpes finneyae* (0 -> 1). ACCTRAN: Diplocaulidae (0 -> 1), Neoreptilia (0 -> 1). DELTRAN: *Diplocaulus sp.* (0 -> 1), *Milleropsis pricei* (0 -> 1).

334. Supraglenoid foramen: absent (0); present (1).

A2001 (c.157), Rea2003 (c.235), RC2007 (c.246), ML2019 (c.201), Hea2013 (c.196), Pea2017 (c.158)

A distinct supraglenoid foramen is present in the outgroup (Clack & Finney, 2005; Rawson et al., 2021), temnospondyls (Sigurdsen & Bolt, 2010; Arbez et al., 2022), embolomeres such as *Archeria* (Holmes, 1989), seymouriamorphs (Klembara, 1997; Berman et al., 2000) and diadectamorphs (Kennedy, 2010). Absence of a distinct glenoid foramen occurs sporadically in *Greererpeton* (Smithson, 1981) and a small number of crown amniotes including *Casea*

(Olson et al., 1968), *Archaeovenator* (Reisz & Dilkes, 2003) and *Milleretta* (Gow, 1972) and *Youngina* (Gow, 1974).

Unambiguous: *Pantylus cordatus* (0 -> 1), *Procynosuchus delaharpeae* (1 -> 0), Reptilia (1 -> 0), *Greererpeton burkemorani* (1 -> 0). ACCTRAN: Nectridea (0 -> 1), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* (1 -> 0). DELTRAN: Diplocaulidae (0 -> 1), *Casea broilii* (1 -> 0).

335. Supraglenoid foramen location: posterior to the apex of the spuraglenoid buttress (0); located on or anterior to the apex of the buttress (1); supraglenoid foramen absent (inapplicable).

FB2020 (c240). Modified from B2012 (c.180), Rea1992 (c.82), Fea2011 (c.112) Sea2018 (c.129).

The plesiomorphic condition (state 0) in which the supraglenoid is located posterior to the dorsal apex of the supraglenoid buttress is present in stem amniote taxa, such as seymouriamorphs (Klembara, 1997; Berman et al., 2000), diadectamorphs (Kennedy, 2010) and captorhinomorphs (Fox & Bowman, 1966). The supraglenoid foramen is located anterior to the apex of the glenoid buttress (state 1) in sphenacodontids (Romer et al., 1940; Laurin, 1993), protorothyridids (Carroll, 1969), and araeoscelidians (Reisz, 1981; Reisz et al., 1984).

Unambiguous: Synapsida (0 -> 1). ACCTRAN: *Recumbirostra*(0 -> 1), Edaphosauridae (1 -> 0). DELTRAN: *Pantylus cordatus* (0 -> 1), *Edaphosaurus boanerges* (1 -> 0), *Paleothyris acadiana* (0 -> 1).

336. Number of coracoid foramina: none (0); one (1); two (2). (ordered).

A2001 (c.158), Hea2013 (c.197), Pea2017 (c.159).

Most taxa included in this analyses possess a single coracoid foramen. A small number of taxa possess no coracoid foramina, such as *Edaphosaurus* (Modesto, 1995), *Aerosaurus* (Langston & Reisz, 1981), *Archaeovenator* (Reisz & Dilkes, 2003), *Brachydectes* (Pardo et al., 2016) and *Whatcheeria* (Rawson et al., 2021). Two foramina are present in *Greererpeton* (Smithson, 1981) and *Seymouria* (Berman et al., 2000).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Asaphestera intermedia* (1 -> 2), *Aerosaurus wellesi* (1 -> 0), *Archaeovenator hamiltonensis* (1 -> 0), *Seymouria sanjuanensis* (1 -> 2). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), Edaphosauridae (1 -> 0), *Greererpeton burkemorani* (1 -> 2). DELTRAN: Tetrapoda (0 -> 1), *Edaphosaurus boanerges* (1 -> 0), *Greererpeton burkemorani* (0 -> 2).

337. Scapulocoracoid dorsal blade: transversely narrow (0); large, broad plate (1).

Pea2017 (c.360).

Lysorophians Pardo et al., 2016) possess a distinctly transversely narrow scapulocoracoid blade, which is still present but highly reduced in ossification.

Unambiguous: *Brachydectes newberryi* (1 -> 0).

338. Number of coracoids: one (0); two (1).

FB2020 (c.244), Gea1988 (c.148), LR1995 (c.95), Mea2008 (c.85), B2012 (c.184), Sea2018 (c.133).

Stem amniotes such as seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005) and diadectamorphs (Kennedy, 2010) have a single ossified element in the position of the coracoid. Most early amniotes crownwards of diadectamorphs have two ossifications in the same position, thus regarded as two coracoids (Ford & Benson, 2020), such as captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), *Araeoscelis* (Reisz et al., 1984), and synapsids (e.g. Romer et al., 1940; Bolt & Scott, 1995; Campione & Reisz, 2010). In many taxa the anterior and posterior ossifications of the coracoid fuse in mature specimens and the suture is lost. Immature specimens of *Petrolacosaurus* show post-mortem separation of the anterior and posterior coracoids (Reisz, 1981), although there are no sutures separating the coracoids in adult specimens of *Petrolacosaurus*. A single coracoid is also present in the reptiles *Youngina* (Gow, 1974) and *Milleretta* (Gow, 1972).

ACCTRAN: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), *Petrolacosaurus kansensis* (1 -> 0), Reptilia (1 -> 0). DELTRAN: Synapsida (0 -> 1), *Araeoscelis gracilis* (0 -> 1), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (0 -> 1).

339. Separately ossified cleithrum: absent (0); present (1).

Hea2013 (c.193), Pea2017 (c.155).

Unambiguous: *Archaeovenator hamiltonensis* (1 -> 0). ACCTRAN: Aïstopoda (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (1 -> 0). DELTRAN: *Lethiscus stocki* + *Phlegethontia linearis* (1 -> 0), Varanopidae (1 -> 0).

340. Cleithrum dorsal expansion: absent, cleithrum is simple rod without dorsal expansion (0); present (1).

LR1997 (c.127), Lea1998 (c.123), Hea2013 (c.192), Pea2017 (c.154).

Most stem tetrapod taxa that possess a cleithrum have a dorsal expansion (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021). A dorsal expansion is also

observed in the temnospondyls *Balanerpeton* (Milner & Sequeira, 1993) and *Dendrerpeton* (Arbez et al., 2022), and in *Gerobatrachus* (Anderson et al., 2008), as well as the anthracosaur *Archeria* (Holmes, 1989), and diplocaulid Nectrideans (Douthitt, 1917; Milner, 2018). In some other taxa, particularly seymouriamorphs (Klembara, 1997; Berman et al., 2000), diadectamorphs (Berman et al., 1998; 2004; Kennedy, 2010), and microsaurs (Carroll & Gaskill, 1978; as well as *Scincosaurus*, a taxon formerly interpreted as a Nectridean but placed with the Microsauria here; Milner & Ruta, 2009), the cleithrum is still present but it has become reduced in size to a simple, rod-like shape.

Unambiguous: Diplocaulidae (0 -> 1), *Tuditanus punctulatus* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0), Adelospondyli (0 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Adelogyrinus simorhynchus* (0 -> 1).

341. Postbranchial laminae on cleithrum: absent (0); present (1).

Rea2003 (c.226), RC2007 (c.237), ML2019 (c.192), Cea2019 (c.242), Pea2017 (c.348), Lea1998 (c.124).

Postbrachial laminae are plesiomorphically present in a number of Carboniferous and Devonian stem tetrapods such as *Whatcheeria* (Rawson et al, 2021) and *Greererpeton* (Smithon, 1981). The lamina is a narrow sheet of bone projecting anteriorly from the anterior edge of the cleithrum.

Unambiguous: *Greererpeton burkemorani* (0 -> 1), *Whatcheeria deltae* (0 -> 1).

342. Cleithrum: ornamented (0), unornamented (1).

Modified from Cea2019 (c241).

Unambiguous: Nectridea (1 to 0).

343. Humerus length along long axis relative to midtrunk vertebral length: shorter than four times the anteroposterior length of the anteroposteriorly longest midtrunk vertebra (0); equal to or longer than four times the length of the longest midtrunk vertebra (1).

A2001 (c.164), Rea2003 (c.249, c.255), RC2007 (c.260, c.266), Hea2013 (c.203), Pea2017 (c.164), ML2019 (c.219).

The cutoff for the states of this character are based on the states in the previous analyses referenced above. The longest measurement along the long axis of the humerus, from the proximal to the distal extremities, are taken. Almost all included taxa in this analysis have a humerus that is at least four times the length of the anteroposteriorly longest vertebra.

However, limb reduction is widespread and present in taxa including *Westlothiana*, most microsaurs (Carroll & Gaskill, 1978; Carroll et al., 1991), *Brachydectes* (Wellstead, 1991) and nectrideans (Douthitt, 1917; Milner & Ruta, 2009; Milner, 2018). Some seymouriamorphs also show a relatively short humerus (Klembara, 1997; Klembara & Ruta, 2005).

Unambiguous: *Diadectes abistus* (1 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0), *Pederpes finneyae* (1 -> 0). ACCTRAN: *Recumbirostra*(0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0). DELTRAN: Aïstopoda (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* (1 -> 0), *Westlothiana lizziae* (1 -> 0).

344. Humerus length relative to maximum diameter of distal end: less than three times longer than maximum distal end width (0); more than three times longer than distal end width (1).

RC2007 (c.260).

The metric cut off point is selected following the source of this character, Ruta & Coates (2007), who describe a survey of humerus proportions in all taxa. State 1 describes a slender humerus, and is observed in *Doleserpeton* (Sigurdsen & Bolt, 2010) and *Gerobatrachus* (Anderson et al., 2008), *Paleothyris* (Carroll, 1969), araeoscelidians (Reisz, 1981; Reisz et al., 1984), *Erpetonyx* (Modesto et al., 2015), and *Brachydectes* (Pardo et al., 2016).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Cardiocephalus sp.* (0 -> 1), *Westlothiana lizziae* (0 -> 1), Araeoscelidia (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* + *Dendrerpeton helogenes* (0 -> 1). DELTRAN: *Erpetonyx arsenaultorum* (0 -> 1), *Paleothyris acadiana* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1).

345. Portion of humeral shaft length along long axis proximal to entepicondyle relative to humeral head width: length of portion of shaft smaller than humeral head width (0); portion of shaft longer than humeral head width (1).

RC2007 (c.264), ML2019 (c.217).

The humeral head width is the maximum distance between the anterior and posterior margins in the plane of its dorsoventral flattening. The shaft length is the longest possible measurement of length along the long axis of the humerus. Stem tetrapods possess short, robust humeri (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021). In most ingroup taxa, the humerus is relatively elongate and slender when compared to the outgroup, but is nonetheless sufficiently robust to be scored as state 1 for this character in a small number taxa. These include *Diadectes* (Berman et al, 1998; MNG 10553, 10554) and

seymouriamorphs (Berman et al., 2000; Klembara & Ruta, 2005), which have robustly ossified skeletons.

Unambiguous: Tetrapoda (0 -> 1), *Keraterpeton galvani* (1 -> 0), *Diadectes abistus* (1 -> 0). ACCTRAN: Seymouriamorpha + *Gephyrostegus bohemicus* (1 -> 0), *Discosauriscus austriacus* (0 -> 1). DELTRAN: *Ariekanerpeton sigalovi* (1 -> 0), *Seymouria sanjuanensis* (1 -> 0).

346. Degree of torsion in humerus: less than 80 degrees (0); more than 80 degrees (1).

A2001 (c.161), Cea2016 (c.180), Cea2019 (c.180), Hea2013 (c.200), Pea2017 (c.161).

Stem tetrapods have a low degree of tension between the proximal and distal ends of the humerus (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021). This is measured by comparison of the orientation of the plane of the proximal and distal ends. A high degree of tension in the humerus is widely present across the ingroup taxa. However, some stem tetrapods such as *Archeria* (Holmes, 1989) or *Silvanerpeton* (Ruta & Clack, 2006), show around 20 to 30 degrees of torsion. This feature is variable in other taxa: *Casea* (Olson et al., 1968), which lacks significant torsion, *Dimetrodon* (Romer et al., 1940), which has around 35 to 60 degrees of torsion, or diplocaulid nectrideans (Douthitt, 1917; Milner, 2018) which range from very little torsion to a maximum torsion of approximately 45 degrees.

Unambiguous: Sphenacodontidae (1 -> 0), Temnospondyli (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Aïstopoda (1 -> 0), *Scincosaurus crassus* (0 -> 1), Caseasauria (1 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (0 -> 1), *Brachydectes* nweberryi (1 -> 0), Diplocaulidae (1 -> 0), *Casea broilii* (1 -> 0), *Seymouria sanjuanensis* (0 -> 1).

347. Latissimus dorsi process position relative to ectepicondyle: aligned with ectepicondyle (0); offset anteriorly relative to ectepicondyle (1).

Rea2003 (c.238), RC2007 (c.249), Cea2016 (c.185), ML2019 (c.204), Cea2019 (c.185).

If the greater axis of the entepicondyle is extended proximally, it can be aligned with the latissimus dorsi process, in those taxa where both structures are readily indistinguishable.

ACCTRAN: Tetrapoda + *Baphetes sp.* (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (1 -> 0), Aïstopoda (0 -> 1), Edaphosauridae + Sphenacodontia (0 -> 1), Diadectamorpha (0 -> 1). DELTRAN: *Scincosaurus crassus* (0 -> 1), *Dimetrodon sp.* (0 -> 1), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Baphetes sp.* (0 -> 1).

348. Humerus shaft shape: straight (0); L-shaped (1).

Modified from Cea2016 (c.181), ML2019 (c.214).

Stem tetrapods possess a distinctly L-shaped humerus (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021), in which the distal end of the humerus is expanded largely asymmetrically relative to the position of the shaft. In almost all crown tetrapods, the proximal and distal ends are roughly symmetrically expanded relative to the shaft, so the main anteroposterior axis of the humerus passes roughly through the midpoint of both the proximal and distal ends. *Archeria* (Holmes, 1989) and *Silvanerpeton* (Ruta & Clack, 2006), however, do possess a stem-tetrapod like L-shaped humerus, corroborating recent views that these taxa may represent stem tetrapods.

Unambiguous: Temnospondyli (1 -> 0); Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0).

349. Humerus shaft waisting: not waisted (0); waisted (1).

Rea2003 (c.247), RC2007 (c.258), Cea2016 (c.181), ML2019 (c.212, c.214).

A waisted humerus describes the condition in which the proximal and distal ends of the humerus are both expanded, and the shaft is narrowed, so that the anterior and posterior margins of the shaft are concave in shape. The distribution of states of this character is almost identical to that of ch.290, as humeri tend to be straight and waisted, or L-shaped and not waisted. However, the humerus of *Keraterpeton* (Milner, 2018), the humerus is both straight and not waisted, and as such these are retained as two separate characters.

Unambiguous: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Keraterpeton galvani* (1 -> 0), Temnospondyli (0 -> 1).

350. Distinct supinator process on humerus: absent (0); present (1).

LR1997 (c.133), Lea1998 (c.131), A2001 (c.163), Rea2003 (c.239), RC2007 (c.250), Cea2016 (c.190), ML2019 (c.205), Cea2019 (c.190), Hea2013 (c.202), Pea2017 (c.163).

The supinator process is situated proximal to the ectepicondyle and projects from the main body of the distal end of the humerus (Romer, 1956). The supinator attachment area may be represented by faint rugosities, or be a conspicuous blunt process detaching from the distal part of the anterior surface of the humerus. A supinator process is present in most included taxa but is absent in temnospondyls and *Gerobatrachus* (Milner & Sequeira, 1993; Anderson et al., 2008; Sigurdsen & Bolt, 2010; Arbez et al., 2022), most former "lepospondyls" including *Brachydectes* (Pardo et al., 2016), nectrideans (Douthitt, 1917; Milner & Ruta, 2009; Milner, 2018) and microsaurs (Carroll & Gaskill, 1978), as well as *Discosauriscus*

(Klembara, 1997), *Hylonomus* (Carroll, 1964), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), *Milleretta* (Gow, 1972) and *Youngina* (Gow, 1974).

Unambiguous: *Echinerpeton intermedium* (1 -> 0), *Discosauriscus austriacus* (1 -> 0), Temnospondyli except *Edops craigi* (1 -> 0), *Pederpes finneyae* (1 -> 0). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* (1 -> 0), *Westlothiana lizziae* (0 -> 1), Synapsida (0 -> 1), *Paleothyris acadiana* (0 -> 1), Diadectamorpha (0 -> 1). DELTRAN: Neoreptilia (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 0), *Hylonomus lyelli* (1 -> 0), *Solenodonsaurus janenschi* (1 -> 0).

351. Humerus, supinator process: transversely broad and extends laterally or anterolaterally (0); transversely narrow and almost confluent with humeral shaft (1); inapplicable, supinator process is low or absent (inapplicable).

FB2020 (c254). Modified from LR1995 (c.101), DR1997 (c.126), Rea2007 (c.101), SS2015 (c.125), Mea2015 (c.143), Mea2018 (c.72).

A supinator process that is confluent with the humeral shaft has previously been considered a character that unites diapsid reptiles (Laurin & Reisz, 1995; Ford & Benson, 2020) and as such as included in this analysis. It is observed in this analysis in araeoscelidians (Reisz, 1981; Reisz et al., 1984) and parapleurotan stem reptiles such as *Youngina* (Gow, 1972; 1974).

ACCTRAN: Amniota (0 -> 1), Synapsida (1 -> 0). DELTRAN: Araeoscelidia (0 -> 1), Neoreptilia (0 -> 1).

352. Distinct ectepicondyle on humerus: ectepicondyle is absent, low or indistinct (0); ectepicondyle is high and well defined (1).

LR1997 (c.134), Lea1998 (c.133), Rea2003 (c.244), RC2007 (c.255), Cea2016 (c.192), Cea2019 (c.192). Modified from a division of ML2019 (c.210).

The ectepicondyle is a ridge that runs on the extensor surface of the humerus and may resemble a thick keel, but varies in shape and size across various taxa. It is present in most taxa, although it is absent in *Brachydectes* (Wellstead, 1991) which has a very reduced appendicular skeleton, as well as dissorophoid temnospondyls (Sigurdsen & Bolt, 2010) and *Gerobatrachus* (Anderson et al., 2008).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Echinerpeton intermedium* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Paleothyris acadiana* (1 -> 0).

353. Entepicondyle width relative to humeral length: less than half of humeral length (0); more than half of humeral length along long axis (1).

LR1997 (c.136), Lea1998 (c.135), Rea2003 (c.252), Cea2016 (c.195), RC2007 (c.263). Modified from Cea2019 (c.194, c.195).

The entepicondyle width is measured in the plane of the surface of the entepicondyle. The humerus length is the maximum distance between its proximal and distal extremities. A large entepicondyle relative to the humerus size is present in stem tetrapods (Beaumont, 1977; Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021) and *Silvanerpeton* (Ruta & Clack, 2006).

Unambiguous: Tetrapoda (1 -> 0), *Silvanerpeton miripedes* (0 -> 1).

354. Ectepicondylar foramen: absent (0); present (1).

RC2007 (c.254), LR1997 (c.137), Lea1998 (c.136), ML2019 (c.209), Rea2003 (c.242).

A foramen in the ectepicondyle is widespread among total-group amniotes such as *Edaphosaurus* (Modesto, 1995) and *Araeoscelis* (Reisz et al., 1984).

Unambiguous: *Araeoscelis gracilis* (0 -> 1). ACCTRAN: Edaphosauridae (0 -> 1). DELTRAN: *Edaphosaurus* boangerges (0 -> 1).

355. Entepicondylar foramen: absent (0); present (1).

LR1997 (c.138), Lea1998 (c.137), A2001 (c.160), Rea2003 (c.243), RC2007 (c.253), ML2019 (c.208), Hea2013 (c.199).

An entepicondylar foramen is present in almost all included taxa. It is absent in a variety of both lepospondyl (e.g. Carroll & Gaskill, 1978; Pardo et al., 2016; Milner, 2018) and temnospondyl (Romer & Witter, 1942; Sigurdsen & Bolt, 2010) taxa. It is also absent in *Orobates* (Berman et al., 2004).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Keraterpeton galvani* (1 -> 0), *Cardiocephalus sp. + Euryodus sp. + Huskerpeton englehorni* (1 -> 0), *Westlothiana lizziae* (1 -> 0), *Orobates pabsti* (1 -> 0), *Doleserpeton annectens + Gerobatrachus hottoni* (1 -> 0), *Edops craigi* (1 -> 0).

356. Olecranon process: unossified (0); ossified (1).

LR1997 (c.140), Lea1998 (c.139), A2001 (c.166), Rea2003 (c.258), RC2007 (c.271), ML2019 (c.224), Cea2019 (c.240), Hea2013 (c.205), Pea2017 (c.166), Hea2013 (c.142).

A hook-like process projecting from the proximal end of the ulna is present in most stem tetrapods (Smithson, 1981; Rawson et al., 2021). It is also present in almost all of the ingroup

taxa in this analysis. It is absent, however, in a number of disparate taxa in multiple separate clades, including *Silvanerpeton* (Ruta & Clack, 2006) and *Solenodonsaurus* (Danto et al., 2012), the seymouriamorphs *Ariekanerpeton* and *Discosauriscus* (Klembara, 1997; Klembara & Ruta, 2005), *Diadectes* (Berman et al., 1998), the microsaurs *Microbrachis* and *Cardiocephalus* (Carroll & Gaskill, 1978), *Petrolacosaurus* (Reisz, 1981), and the synapsids *Varanops* (Campione & Reisz, 2010) and *Pantelosaurus* (Spindler, 2016).

Unambiguous: *Microbrachis pelikani* (1 -> 0), *Cardiocephalus sp.* (1 -> 0), *Varanops brevirostris* (1 -> 0), *Pantelosaurus saxonicus* (1 -> 0), *Petrolacosaurus kansensis* (1 -> 0), *Diadectes abistus* (1 -> 0), *Solenodonsaurus janenschi* (1 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0), *Pederpes finneyae* (1 -> 0).

357. Length of ulna along long axis in relation to length of radius along long axis: ulna shorter than radius (0); ulna and radius equivalent in length (1); ulna longer than radius (2). (ordered).

Lea1998 (c.140), Rea2003 (c.257), ML2019 (c.222), Cea2019 (c.202), RC2007 (c.269), Cea2016 (c.202), Pea2017 (c.357).

Unambiguous: *Brachydectes newberryi* (2 -> 0), *Microbrachis pelikani* (2 -> 1), *Youngina capensis* (2 -> 0), *Limnoscelis paludis* (2 -> 1), *Pederpes finneyae* (2 -> 1). ACCTRAN: *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (2 -> 1), Edaphosauridae (2 -> 0), Araeoscelidia (2 -> 1). DELTRAN: *Cardiocephalus sp.* + *Euryodus sp.* (2 -> 1), *Edaphosaurus boanerges* (2 -> 0), *Petrolacosaurus kansensis* (2 -> 1).

358. Ratio of radius length along long axis:humerus length along long axis: <0.5 (0); 0.51-0.7 (1); 0.71-1 (2). (ordered).

A2001 (c.165), Hea2013 (c.204), Rea2003 (c.256), RC2007 (c.268), Pea2017 (c.165), ML2019 (c.221).

The division of states in this character is based on those in the previous analyses referenced above. In the outgroup and most other stem tetrapods, the radius is large in size to the humerus, reaching roughly one half to 70% of humerus length (Smithson, 1981; Clack & Finney, 2005; Rawson et al., 2021). In some clades, such as diplocaulid nectrideans (Douthitt, 1917; Milner, 2018) and some crown amniotes (e.g. Romer et al., 1940; Gow, 1972; 1974; Reisz, 1981), the radius is almost as long as the humerus. In many microsaurs, the radius is less than half of the length of the humerus (Carroll & Gaskill, 1978).

Unambiguous: Diplocaulidae (1 -> 2), *Hyloplesion longicostatum* (1 -> 0), Amniota (1 -> 2), *Ariekanerpeton sigalovi* (1 -> 2), *Gephyrostegus bohemicus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 2), *Baphetes sp.* (1 -> 0). ACCTRAN: Adelospondyli (1 -> 2), *Recumbirostra*(1 -> 0),

Euryodus sp. (0 -> 1), Edaphosauridae (2 -> 1). DELTRAN: *Utaherpeton franklini* (1 -> 2), *Cardiocephalus sp.* (1 -> 0), *Pantylus cordatus* (1 -> 0), *Edaphosaurus boanerges* (2 -> 1).

359. Digits present on manus: absent (0); present (1); manus or entire forelimb absent (inapplicable).

Rea2003 (c.313), RC2007 (c.333).

This character does not vary among the ingroup taxa included in this analysis, and digits are only absent in *Eusthenopteron* and *Tiktaalik* amongst the taxa included here. The limbs are lost completely in aïstopods (Carroll, 1998; Anderson, 2002; Anderson et al., 2003) and adelospondyls (Andrews & Carroll, 1991) and they are therefore scored as inapplicable. However, it is retained to allow for future inclusion of deeper stem tetrapod taxa at the level of panderichthyiids in which the digits on the manus are absent (Ruta et al., 2003).

360. Number of digits on manus: three (0); four (1); five (2); manus or entire forelimb absent (inapplicable). (ordered).

ML2019 (c.276), LR1997 (c.141), Lea1998 (c.141), A2001 (c.168), Cea2019 (c.226), Hea2013 (c.208), Pea2017 (c.169). Modified from Rea2003 (c.314, c.315, c.316), RC2007 (c.334, c.335, c.336).

Almost all taxa included in this analysis have five manual digits. Temnospondyls have four digits on the manus (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010; Arbez et al., 2022), as does *Diadectes* (Berman et al., 1998). Many former "lepospondyls" have a lower number of manual digits as well, including *Brachydectes* (Pardo et al., 2016), *Scincosaurus* (Milner & Ruta, 2009) and non-microbracomorph microsaurs (Carroll & Gaskill, 1978) have four manual digits. Microbrachomorph microsaurs have just three digits on the hand (Carroll & Gaskill, 1978).

Unambiguous: *Diadectes abistus* (2 -> 1). ACCTRAN: Diplocaulidae (1 -> 2), Temnospondyli (2 -> 1). DELTRAN: *Keraterpeton galvani* (1 -> 2), *Hyloplesion longicostatum* (1 -> 0), *Microbrachis pelikani* (1 -> 0), Temnospondyli except *Edops craigi* (2 -> 1).

361. Ossification of carpals: completely unossified (0); at least partially ossified (1).

A2001 (c.167), Hea2013 (c.206), Pea2017 (c.167).

The outgroup taxa lack ossified carpals (Clack & Finney, 2005; Rawson et al., 2021), but almost all ingroup taxa have at least some ossified carpals. Some seymouriamorphs (Klembara, 1997; Klembara & Ruta, 2005), *Silvanerpeton* (Ruta & Clack, 2006; UMZC T.1317), *Brachydectes* (Wellstead, 1991), diplocaulid nectrideans (Douthitt, 1917; Milner,

2018) and a small number of microsaurs (Carroll & Gaskill, 1978; Carroll et al., 1991) have carpals that are completely unossified, despite have a well ossified limb and manus.

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1), *Scincosaurus crassus* (0 -> 1), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0).

362. Shape of manual terminal phalanges: similar to intermediate phalanx (0), tapering distally but lacking distal ventral curvature (1); taper distally to a point and curve ventrally (1).

FB2020 (c266).

This character was a novel character in Ford & Benson (2020). It describes a keratinous claw, which sheaths the ungual (terminal) phalanx of the manus. In amniotes more derived than former "lepospondyls", the ungual tapers to a point distally with a distinct ventral curvature (state 1) (e.g. Romer et al., 1940; Fox & Bowman, 1966; Olson et al., 1968; Carroll, 1969; Gow, 1972; 1974; Campione & Reisz, 2010). In stem amniote taxa such as seymouriamorphs (Klembara, 1997; Berman et al., 2000; Klembara & Ruta, 2005) and diadectomorphs (Berman et al., 2004; Kennedy, 2010) the ungual phalanx is hoof-like.

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1).

363. Pelvis ossification: poorly ossified or absent (0); elements sutured (1); elements fused into single ossification (2).(ordered).

A2001 (c.169), Cea2016 (c.212), Cea2019 (c.212), Hea2013 (c.209), Pea2017 (c.170), LR1997 (c.142), Lea1998 (c.142).

The pelvis is completely absent in adelogyrinids (Andrews & Carroll, 1991; Clack et al., 2019), and it is absent along with the whole appendicular skeleton in aïstopods (Carroll, 1998; Anderson, 2002; Anderson et al., 2003). Generally, across almost most taxa included in this analysis sutures are visible. However, a small number of disparate taxa show a fused pelvis with no sutures visible, such as *Doleserpeton* (Sigurdsen & Bolt, 2010), *Petrolacosaurus* (Reisz, 1981), *Captorhinus* (Fox & Bowman, 1966) and *Scincosaurus* (Milner & Ruta, 2009).

Unambiguous: Adelospondyli (1 -> 0), *Scincosaurus crassus* (1 -> 2), Aïstopoda (1 -> 0), *Petrolacosaurus kansensis* (1 -> 2), *Discosauriscus* sp. (1 -> 0), *Doleserpeton annectens* (1 -> 2), *Whatcheeria deltae* (1 -> 2). ACCTRAN: *Hapsidopareion lepton* (1 -> 0), Captorhinidae (1 -> 2). DELTRAN: *Hapsidopareion lepton* (1 -> 0), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (1 -> 2).

364. Number of pelvic obturator foramina: none (0); one (1); two or more (2). (ordered).

RC2007 (c.279), ML2019 (c.230).

In the outgroup, in *Whatcheeria* (Rawson et al, 2021), three obturator foramina on the pelvis are observed. In almost all ingroup taxa, there is a single obturator foramen. However, a small number of taxa have no obturator foramina, namely *Scincosaurus* (Milner & Ruta, 2009) and *Brachydectes* (Pardo et al., 2016).

Unambiguous: *Eocasea martini* (1 -> 0), *Hylonomus lyelli* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (2 -> 1), DELTRAN: *Whatcheeria deltae* (1 -> 2).

365. Dorsal iliac blade: single blade (0); partially bifurcate (1); bifurcated into two dorsal processes (2). (ordered).

LR1997 (c.143), Lea1998 (c.143), A2001 (c.170), Rea2003 (c.259), RC2007 (c.272), Cea2016 (c.213), ML2019 (c.255), Cea2019 (c.213), Hea2013 (c.211), Pea2017 (c.172).

In the outgroup (Clack & Finney, 2005; Rawson et al., 2021) and the stem tetrapod *Baphetes* (Beaumont, 1977), the iliac blade is divided into two processes; a more dorsally projecting process, and a more posteriorly projecting process. This character is also present in a sporadic set of other taxa, including, *Gephyrostegus* (Klembara et al, 2014), the microsaur *Tuditanus* (Carroll & Gaskill, 1978), the diadectamorph *Orobates* (Berman et al., 2004) and the anthracosaur *Archeria* (Holmes, 1989).

Unambiguous: *Tuditanus punctulatus* (0 -> 1), *Asaphestera intermedia* (0 -> 1), *Gephyrostegus bohemicus* (0 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Diadectes abistus* + *Orobates pabsti* (0 -> 1), Embolomeri (0 -> 1), *Baphetes sp.* (0 -> 1). DELTRAN: Tetrapoda (1 -> 0), *Orobates pabsti* (0 -> 1), *Archeria crassidisca* (0 -> 1), *Greererpeton burkemorani* (1 -> 0).

366. Ilium, postacetabular process, length: short ends level with or anterior to posterior margin of iliac body (0), long, extends posterior to iliac body (1).

367. Transverse pelvic ridge: absent (0); present (1).

Rea2003 (c.261), RC2007 (c.275), ML2019 (c.228).

State 1 of this character describes a transverse ridge sweeping from immediately dorsal to acetabulum, and running obliquely in posterodorsal direction. It is found in diadectamorphs (Berman et al., 2004; Kennedy, 2010) and seymouriamorphs (Klembara, 1997; Berman et al.,

2000), as well as the microsaur *Tuditanus* (Carroll & Gaskill, 1978) and the temnospondyl *Dendrerpeton* (Arbez et al, 2022).

Unambiguous: *Tuditanus punctulatus* (0 -> 1), Diadectamorpha (0 -> 1), *Dendrerpeton helogenes* (0 -> 1). ACCTRAN: Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1). DELTRAN: Seymouriamorpha (0 -> 1).

368. Length of puboischiadic plate in relation to length of trunk vertebrae: three (0); four (1); five (2); six (3). (ordered).

A2001 (c.171).

Unambiguous: *Brachydectes newberryi* (1 -> 0), Amniota (3 -> 1), Edaphosauridae + Sphenacodontia (1 -> 3), *Diadectes abistus* (3 -> 1), *Greererpeton burkemorani* (3 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (3 -> 1), *Hapsidopareion lepton* (1 -> 0), *Westlothiana lizziae* (1 -> 2), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota + Diadectamorpha (1to3), Varanopidae (1 -> 0). DELTRAN: *Hapsidopareion lepton* (1 -> 0), *Westlothiana lizziae* (3 -> 2), *Varanops brevirostris* (1 -> 0), Seymouriamorpha (3 -> 1).

369. Pubis, pubic tubercle: absent (0), present (1).

370. Distinct internal trochanter: absent (0); present (1).

Rea2003 (c.265), RC2007 (c.280). Modified from a division of LR1997 (c.144), Lea1998 (c.144), A2001 (c.172), Hea2013 (c.212), Pea2017 (c.173).

The internal trochanter may appear as either a weakly developed indistinct area, or a projection, on the anterior surface of the femur (Romer, 1956). An internal trochanter is absent in the outgroup (Clack & Finney, 2005; Rawson et al., 2021) but is present in almost all ingroup taxa with the exception of *Keraterpeton* (Milner, 2018).

Unambiguous: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Diplocaulidae (1 -> 0). DELTRAN: *Keraterpeton galvani* (1 -> 0).

371. Internal trochanter separated from the general surface of the femur shaft by a distinct, trough-like space: absent (0); present (1).

Rea2003 (c.266), RC2007 (c.281), ML2019 (c.231). Modified from a division of LR1997 (c.144), Lea1998 (c.144).

In some taxa, the internal trochanter and the part of the shaft of the femur that it originates from are separated by a deeply notched web of bone. This condition is present in *Greererpeton* (Smithson, 1981), temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt,

2010; Holmes et al., 1998), *Casea* (Olson et al., 1968), *Paleothyris* (Carroll, 1969), captorhinids (Fox & Bowman, 1966; Reisz et al., 2015), diadectamorphs (Berman et al., 1998; 2004; Kennedy, 2010), seymouriamorphs (Klembara, 1997; Berman et al., 2000) and some former "lepospondyls" including *Brachydectes* (Wellstead, 1991), *Scincosaurus* (Milner & Ruta, 2009) and some microsaurs (Carroll & Gaskill, 1978).

Unambiguous: Amniota (1 -> 0), *Hylonomus lyelli* (1 -> 0). ACCTRAN: Diplocaulidae (1 -> 0), Caseasauria + *Echinerpeton intermedium* (0 -> 1), Embolomeri + *Chroniosaurus dongusensis* (1 -> 0). DELTRAN: *Keraterpeton galvani* (1 -> 0), *Casea broilii* (0 -> 1), *Archeria crassidisca* (1 -> 0).

372. Maximum extent of femur adductor crest along length of femur: does not reach mid-shaft length (0); reaches mid-shaft length (1).

Rea2003 (c.268), RC2007 (c.283), ML2019 (c.233). Modified from a division of Lea1998 (c.146).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Araeoscelis gracilis* (1 -> 0), *Seymouria sanjuanensis* (1 -> 0). ACCTRAN: Varanopidae (1 -> 0), Reptilia (1 -> 0). DELTRAN: *Varanops brevirostris* (1 -> 0), *Archaeovenator hamiltonensis* (1 -> 0), *Erpetonyx arsenaultorum* (1 -> 0).

373. Length of femur along long axis relative to maximum width of femoral head: length is less than 5 times the width (0); length is more than 5 times the width (1).

A2001 (c.173), Hea2013 (c.213), Pea2017 (c.174).

The femur is measured as the maximum length along the long axis. The femoral head width is measured as the maximum transverse width from the anterior to posterior extremity of the femoral head. A particularly slender femur (state 1) is present across a small number of taxa from many clades, including *Greererpeton* (Smithson, 1981), *Doleserpeton* (Sigurdsen & Bolt, 2010), *Paleothyris* (Carroll, 1969), *Youngina* (Gow, 1972), *Brachydectes* (Wellstead, 1991), Westlothaina and *Tuditanus* (Carroll & Gaskill, 1978).

Unambiguous: *Brachydectes newberryi* (0 -> 1), *Paleothyris acadiana* (0 -> 1), *Greererpeton burkemorani* (0 -> 1). ACCTRAN: *Belebey vegrandis* + *Erpetonyx arsenaultorum* + *Youngina capensis* (0 -> 1), *Doleserpeton annectens* + *Gerobatrachus hottoni* (0 -> 1). DELTRAN: *Tuditanus punctulatus* (0 -> 1), *Westlothiana lizziae* (0 -> 1), *Youngina capensis* (0 -> 1), *Doleserpeton annectens* (0 -> 1).

374. Femur length along long axis relative to midtrunk vertebral anteroposterior length: shorter than four times the length of the longest

midtrunk vertebra (0); equal to or longer than four times the length of the longest midtrunk vertebra (1).

A2001 (c.174), Rea2003 (c.269), RC2007 (c.284), ML2019 (c.234), Hea2013 (c.214), Pea2017 (c.175).

A “long” femur (state 1) is defined following the distribution of states in Anderson (2001). The femur is substantial in size across most taxa, but shows a smaller size across a variety of clades, particularly within former "lepospondyls", in which most microsaurs (Carroll & Gaskill, 1978) and nectrideans (Douthitt, 1917; Milner, 2018) possess a shorter humerus. A short humerus (state 0) is also present in *Discosauriscus* (Klembara, 1997), *Doleserpeton* (Sigurdsen & Bolt, 2010) and *Silvanerpeton* (Ruta & Clack, 2006).

Unambiguous: *Diadectes abistus* (1 -> 0), *Silvanerpeton miripedes* (1 -> 0), *Chroniosaurus dongusensis* (1 -> 0), *Pederpes finneyae* (1 -> 0). ACCTRAN: *Hyloplesion longicostatum* (0 -> 1), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* + *Micraroter erythrogeois* + *Hapsidopareion lepton* (1 -> 0), *Ariekanerpeton sigalovi* + *Discosauriscus austriacus* (1 -> 0), *Doleserpeton annectens* + *Gerobatrachus hottoni* (1 -> 0). DELTRAN: *Microbrachis pelikani* (1 -> 0), *Cardiocephalus sp.* + *Euryodus sp.* + *Huskerpeton englehorni* (1 -> 0), *Discosauriscus austriacus* (1 -> 0), *Doleserpeton annectens* (1 -> 0).

375. Distinct rugose area on fourth trochanter of femur: absent, fourth trochanter lacks rugose area or is absent (0); present (1).

Rea2003 (c.267), RC2007 (c.282), ML2019 (c.232).

A rough, textured area on the fourth trochanter is present in a small number of disparate taxa, namely *Greererpeton* (Smithson, 1981), *Dimetrodon* (Romer et al., 1940) and *Captorhinus* (Fox & Bowman, 1966).

Unambiguous: *Greererpeton burkemorani* (0 -> 1). ACCTRAN: Sphenacodontia (0 -> 1), Captorhinidae (0 -> 1). DELTRAN: *Dimetrodon sp.* (0 -> 1), *Captorhinus aguti* (0 -> 1).

376. 4th trochanter of the femur: absent (0); present as a raised ridge on the ventral surface of the femoral shaft (1).

FB2020 (c279), Gea1988 (c.193). Modified from N2011 (c.315, c.316), B2012 (c.228), E2016 (c.504).

Close to the distal margin of the intertrochanteric fossa the adductor ridge of the femur may increase in height to form a projection called the 4th trochanter (Romer 1956). A fourth trochanter is present in a number of disparate taxa including stem tetrapods such as *Whatcheeria* (Rawson et al., 2021) and *Greererpeton* (Smithson, 1981), the temnospondyl Dendererpeton (Holmes et al., 1998), the synapsids *Vaughnitis* (Brocklehurst et al., 2016) and

Varanops (Campione & Reisz, 2010), *Captorhinus* (Fox & Bowman, 1966) and most diadectamorphs (Berman et al., 1998; Kennedy, 2010).

ACCTRAN: Tetrapoda + *Baphetes sp.* (1 -> 0), Caseasauria + *Echinerpeton intermedium* + *Vaughnitis smithae* + Varanopidae (0 -> 1), Caseasauria + *Echinerpeton intermedium* (1 -> 0), Captorhinidae (0 -> 1), Diadectamorpha (0 -> 1), *Orobates pabsti* (1 -> 0), Embolomeri + *Chroniosaurus dongusensis* (0 -> 1), *Dendrerpeton helogenes* (0 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0), *Varanops brevirostris* (0 -> 1), *Vaughnitis smithae* (0 -> 1), *Captorhinus aguti* + *Opisthodontosaurus carrolli* (0 -> 1), *Diadectes abistus* (0 -> 1), *Limnoscelis paludis* (0 -> 1), *Caerorachis bairdi* (1 -> 0), *Doleserpeton annectens* (1 -> 0).

377. Rows of tubercles near posterior edge of fibula flexor surface: absent (0); present (1).

Rea2003 (c.273), RC2007 (c.290), ML2019 (c.239).

A row of tubercles near the posterior edge of the surface of the fibula is present in the outgroup, and in the stem tetrapod *Baphetes* (Beaumont, 1977).

ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), *Baphetes sp.* (0 -> 1). DELTRAN: Tetrapoda (1 -> 0), *Greererpeton burkemorani* (1 -> 0).

378. Fibula waisted: no (0); yes (1).

Rea2003 (c.271), RC2007 (c.288), ML2019 (c.237).

As in the case of other limb bones, a waisted shaft implies the presence of a distinct constriction of the shaft of the element, with expanded proximal and distal ends. Almost all included taxa possess a waisted fibula, except for the outgroup.

Unambiguous: *Araeoscelis gracilis* (1 -> 0). ACCTRAN: Adelospondyli (1 -> 0). DELTRAN: *Utaherpeton franklini* (1 -> 0).

379. Flange along posterior edge of tibia: absent (0); present (1).

Rea2003 (c.270), RC2007 (c.287), ML2019 (c.236).

Unambiguous: Tetrapoda (1 -> 0). ACCTRAN: *Diadectes abistus* + *Orobates pabsti* (0 -> 1). DELTRAN: *Orobates pabsti* (0 -> 1).

380. Number of proximal tarsal elements: two, with tibiale, intermedium and proximal centrale fused into astragalus (0); three (1); four or more (2). (ordered).

Rea2003 (c.275), RC2007 (c.291), LR1997 (c.148), Lea1998 (c.148), A2001 (c.178), Hea2013 (c.218), Pea2017 (c.179), ML2019 (c.240).

The fusion of the proximal tarsal elements into an astragalus and calcaneum, with a total of two elements, is seen in all amniote taxa more derived than diadectamorphs (e.g. Romer et al., 1940; Fox & Bowman, 1966; Gow, 1972; 1974; Reisz, 1981). A similar condition is observed in the microsaur *Tuditanus* (Carroll & Gaskill, 1978). The stem tetrapod *Greererpeton* (Smithson, 1981) and the stem amniote *Gephyrostegus* (Klembara et al, 2014) are noted to have more than three ossified tarsals. *Westlothiana* bears four proximal tarsal elements, one more than previously described.

Unambiguous: *Hyloplesion longicostatum* (1 -> 2), *Tuditanus punctulatus* (1 -> 0), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (1 -> 0), *Gephyrostegus bohemicus* (1 -> 2). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (2 -> 1).

381. L-shaped proximal tarsal element: absent (0); present (1).

RC2007 (c.292), ML2019 (c.241), Cea2019 (c.232), Rea2003 (c.276).

In several stem and crown amniotes (e.g. Romer et al., 1940; Carroll, 1969; Gow, 1972; 1974; Reisz, 1981; Modesto, 1995; Reisz & Dilkes, 2003) the proximal tarsal element, either the intermedium or astragalus depending on the level of fusion, carries a shall proximal notch or evacuation. Sometimes this is pronounced, distinctly angular and confers a vaguely L-shaped outline to this tarsal element. This condition is also observed in *Silvanerpeton* (Ruta & Clack, 2006), *Diadectes* (Berman et al., 1998) and *Tuditanus* (Carroll & Gaskill, 1978).

Unambiguous: *Tuditanus punctulatus* (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1), *Eocasea martini* (1 -> 0), *Araeoscelis gracilis* (1 -> 0), *Diadectes abistus* (0 -> 1). ACCTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 0). DELTRAN: *Silvanerpeton miripedes* (0 -> 1), *Caerorachis bairdi* (0 -> 1).

382. Number of distal tarsal elements: five or fewer (0); six (1).

Modified from RC2007 (c.293, c.294), A2001 (c.177), Rea2003 (c.277, c.278), ML2019 (c.242, c.243), Hea2013 (c.217), Pea2017 (c.178).

Unambiguous: Seymouriamorpha + *Gephyrostegus bohemicus* (0 -> 1). ACCTRAN: Araeoscelidia (0 -> 1), Captorhinidae (0 -> 1), Temnospondyli (0 -> 1). DELTRAN: *Tuditanus punctulatus* (0 -> 1), *Pantylus cordatus* (0 -> 1), *Petrolacosaurus kansensis* (0 -> 1), *Captorhinus aguti* (0 -> 1), *Balanerpeton woodi* (0 -> 1).

383. Number of phalanges in third pedal digit: three (0); four (1); more than four.

LR1997 (c.152), Lea1998 (c.152).

Most in-group taxa have four or more pedal digits. This includes stem and crown amniotes, including *Westlothiana* (e.g. Romer & Price, 1940; Carroll, 1969; Gow, 1974; Klembara, 1997; Ruta & Clack, 2006; Reisz & Fröbisch, 2014) and most former "lepospondyls" (e.g. Carroll & Gaskill, 1978; Milner & Ruta, 2009; Milner, 2018). However, the lepospondyl *Brachydectes* (Wellstead, 1991) has three pedal digits, which accompanies its poorly ossified appendicular skeleton, as do Seymouria (Berman et al., 2000) and temnospondyls (Milner & Sequeira, 1993; Sigurdsen & Bolt, 2010).

Unambiguous: *Brachydectes newberryi* (1 -> 0), *Seymouria sanjuanensis* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (1 -> 0), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (0 -> 1), *Whatcheeria deltae* (1 -> 2). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* +Seymouriamorpha (0 -> 1), *Pederpes finneyae* (0 -> 1), *Whatcheeria deltae* (0 -> 2).

384. Number of phalanges in fourth pedal digit: three (0); four (1); five (2). (ordered).

LR1997 (c.153), Lea1998 (c.153).

Unambiguous: *Microbrachis pelikani* (2 -> 1), *Seymouria sanjuanensis* (2 -> 1), *Doleserpeton annectens* (1 -> 0). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (2 -> 1), Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 2), Aïstopoda (2 -> 0). DELTRAN: Amniota + Diadectamorpha + *Solenodonsaurus janenschi* + Seymouriamorpha (1 -> 2).

385. Number of phalanges in fifth pedal digit: two (0); three (1); four (2); five (3). (ordered).

LR1997 (c.154), Lea1998 (c.154).

Unambiguous: *Haptodus garnettensis* (2 -> 1). ACCTRAN: Tetrapoda + *Baphetes sp.* + *Greererpeton burkemorani* (3 -> 2), Aïstopoda (1 -> 0), Diplocaulidae (0 -> 1), *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae (2 -> 1), Seymouriamorpha + *Gephyrostegus bohemicus* (2 -> 1), *Ariekanerpeton sigalovi* (1 -> 2), *Gephyrostegus bohemicus* (1to3), Temnospondyli (2 -> 1). DELTRAN: *Brachydectes newberryi* (1 -> 0), *Scincosaurus crassus* (1 -> 0), *Paleothyris acadiana* (2 -> 1), *Discosauriscus austriacus* (2 -> 1), *Seymouria sanjuanensis* (2 -> 1), *Gephyrostegus bohemicus* (2 -> 3), Temnospondyli except *Edops craigi* (2 -> 1).

386. Tarsus, tibio-astragalar joint: flat (0); tibial ridge fits into astragalar groove (1); inapplicable, astragalus absent (inapplicable).

FB2020 (c284), Gea1988 (c.195), L1991 (c.J9), LR1995 (c.116), Rea2010 (c.107).

A complex tibio-astragular joint was indicated by Laurin & Reisz (1995) as a character that unites diapsid reptiles, which incorporated younginiforms and araeoscelidians. In Ford & Benson (2020), where former "parareptiles" are recovered as the sister clade to younginiforms and closer to the reptile crown than araeoscelidians, state 1 of this character was described to have been independently acquired in araeoscelidians and younginiforms, a result that concurs with the results in this analysis.

Unambiguous: Araeoscelidia (0 -> 1), *Youngina capensis* (0 -> 1).

387. Tarsus, number of centralia: two centralia present (0); only one centrale is present (1).

FB2020 (c291). Modified from DR1997 (c.158), M2004 (c.151), Eea2014 (c.214), Mea2015 (c.162).

Sphenacodontids and edaphosaurids are noted to have two centralia in the tarsus (Romer et al., 1940; Modesto, 1995; Ford & Benson, 2020).

Unambiguous: *Hylonomus lyelli* + *Paleothyris acadiana* + Captorhinidae + Amniota (0 -> 1). ACCTRAN: Aïstopoda (0 -> 1), Synapsida 1 -> 0). DELTRAN: *Tuditanus punctulatus* (0 -> 1), Edaphosauridae + Sphenacodontia (1 -> 0).

388. Metatarsus, ratio of lengths of metatarsals I and IV: equal or greater than 0.42 (0); less than 0.42 (1).

FB2020 (c292). Modified from Eea2014 (c.216), D1998 (c.123), M2004 (c.173), MS2004 (c.123).

Sphenacodontids possess a short fourth metatarsal, which is less than 42% of the length of the first metatarsal (Romer et al., 1940; Laurin, 1993).

Unambiguous: Sphenacodontia (0 -> 1), *Seymouria sanjuanensis* (0 -> 1). ACCTRAN: *Recumbirostra* (0 -> 1), Neoreptilia (0 -> 1). DELTRAN: *Pantylus cordatus* (0 -> 1), *Youngina capensis* (0 -> 1).

389. Pes, digits I and II, length of proximal phalanges relative to metatarsals: proximal phalanges equal to 70% the length of the metatarsals (0), metatarsals longer than proximal phalanges (1)

389. Pes, pedal unguals of digits II-IV: much shorter than all non-ungual phalanges (0), 80-100% the length of one non-ungual phalanx of the same digit (1).

Modified from J2025a (c647).

The pedal unguals of early tetrapodomorphs (e.g., *Greererpeton,* Smithson 1989) are noticeably smaller than non-ungual phalanges, a feature also present in *Westlothiana* and stem amniotes such as *Hylonomus* (Carroll 1974), which is in contrast with crown group amniotes in which the unguals are approximately equal to the length of the non-ungual phalanges or longer (State 1).

Unambiguous: Amniota + Captorhinidae + Diadectomorpha (0 → 1).

Part 4. Ages of included taxa

Taxon	Source	FAD	LAD	ICS stage(s)	Comments
Whatcheeria	Rawson et al, 2021. Lombard & Bolt, 1995	340	340	Viséan	Specimens from Hiemstra Quarry, Iowa (Rawson et al, 2021). The horizons are Viséan V3b in age, c. 340Ma (Lombard & Bolt, 1995).
Pederpes	Clack, 2002. Clack & Finney, 2005.	348	344	Tournasian/ Viséan	From a site in Auchenreoch Glen, north of Dumbarton, Scotland. The site is within the Ballagan Formation, part of the Cementstone Group (Clack & Finney, 2005). Clack (2002) gives a more specific age of 348-344Ma.

Greererpeton	Smithson, 1982. Busanus & Hoare, 1991.	333	323.2	Upper Viséan/ Serpukhovian	From the Bickett Shale of the Bluefield Formation, Mauch Chunk Group, at Greer Limestone Quarry, Monongalia County, West Virginia (Smithson, 1982). The Bickett Shale dates entirely within the North American Chesterian series (Busanus & Hoare, 1991).
Baphetes	Beaumont, 1977	318	308	Westphalian B to D	Material from multiple localities, listed in Beaumont (1977): Albion Mine, Stellarton, Nova Scotia. Part of the Stellarton Group, corresponds to Westphalian C. Earl David's Parrot Coal, Middle Coal Measures of East Fifeshire, Scotland, Westphalian B. Bradford Coal Group, Lancashire, Westphalian C. Upper Freeport Coal, Linton Diamond Mine, Ohio. Westphalian C. Specimens also known from Nyrany, Westphalian D.
Edops	Romer & Witter, 1942. Yang & Kominz, 1999.	298.9	280	Cisuralian	Known from the Moran and Pueblo formations of Texas (Romer & Witter, 1942). These sit after the start of the Permian, within the Wolfcampain North American Stage, but before the start of the Leonardian North American Stage (Yang & Kominz, 1999).
Balanerpeton	Milner & Sequeira, 1993	344	338	Holkerian-Arundian	From the East Kirkton Quarry (Milner & Sequeira, 1993). See Westlothiana for further discussion of age.
Dendrerpeton	Arbez et al, 2021.	319	318	Bashkirian	Division 4 of Joggins Formation, Joggins, Nova Scotia, Canada. Langsettian (= Westphalian A) (Arbez et al, 2021). See Hylonomus for discussion of age of Joggins material.
Doleserpeton	Sigurdsen & Bolt, 2010. MacDougall et al, 2016.	286.7	286.2	Artinskian	Numerus specimens from Lower Permian Fissure Fills of Richards Spur, Fort Sill, Oklahoma (Sigurdsen & Bolt, 2010). Precisely dated to the ages shown by MacDougall et al (2016).
Gerobatrachus	Anderson et al, 2008	280	270.6	Kungurian/ Roadian	From Don's Dump Fish Quarry, Clear Fork Group, Baylor County, Texas, Leonardian in age (Anderson et al, 2008).
Adelogyrinus	Andrews & Carroll, 1991	337.5	333	Viséan	Dunnet Shale, Upper Oil Shale Group. Part of the regional Asbian Stage of the Viséan (Andrews & Carroll, 1991)
Acherontiscus	Clack et al, 2019	326.4	326		The only known specimen lacks field or locality data. However, recent work has refined the age to the Pendleian, early Serpukhovian (Clack et al, 2019)
Anthracosaurus	Panchen, 1977	318	315.2	Late Bashkirian	From the Airdrie or Mushet's Black Band Ironstone, Lanarkshire, Scotland, which correlates with the Westphalian B (Panchen, 1977)

Archeria	Holmes, 1989	290.1	283.5	Artinskian	Geraldine bone beds, part of the Admiral Formation (Holmes, 1989). See Dimetrodon for further discussion of age of this formation.
Silvanerpeton	Ruta & Clack, 2006	344	338	Holkerian-Arundian	From the East Kirkton Quarry (Ruta & Clack, 2006) See Westlothiana for further discussion of age.
Gephyrostegus	Klembara et al, 2014. Ford & Benson, 2020.	311	307	Late Moscovian	Plattenkhole of Humboldt Mine, Nýřany, Plzeň-Manětín Basin, Czech Republic, Asturian (Klembara *et al.* 2014). The Asturian is equal to the Westphalian D, synchronous with the Late Moscovian (Ford and Benson, 2020).
Seymouria	Berman et al, 2000. Laurin, 1996. Stemmerik et al, 2000.	281	270.6	Kungurian	S. Baylorensis is from the Clear Fork Group, within the Leonardian period (Laurin, 1996). European specimens are from the Bromacker locality (Berman et al, 2000) which falls most reliably within the range of 281-276Ma (Stemmerik et al, 2000).
Ariekanerpeton	Klembara & Ruta, 2005	300	288	Early Permian	Sarytaypan locality, Leninabad province, Kuramin Ridge, Adrasman district, Tajikistan. These beds are most likely coeval with the Lower Rotliegende of central Europe but this is somewhat uncertain (Klembara & Ruta, 2005). The range of the Lower Rotliegende is given as 288-300Ma (Stemmerik et al, 2000).
Discosauriscus	Klembara, 1997. Werneburg & Schneider, 2006.	285.5	283	Artinskian	Materail from the Bacov Horizon, Boskovice Furrow, Letovice, Czech Republic (Klembara, 1997). The Discosauriscus bearing horizon of Letowice can be dated to 285.5-283Ma (Werneburg & Schneider, 2006).
Solenodonsaurus	Danto et al, 2012	311	307	Late Moscovian	Nyrany, Czech Republic (Danto et al, 2012). Nyrany specimens are from the Westphalian D, see Gephyrostegus.
Westlothiana	Smithson et al, 1994. Smith et al, 1993.	344	338	Holkerian-Arundian	From the East Kirkton Quarry (Smithson et al, 1994). The East Kirkton outcrop sits within the West-Lothian Oil-Shale Formation, which can be assigned to Holkerian-Arundian age (Garza et al., ,).
Tuditanus	Carroll & Gaskill, 1978	309.5	308	Moscovian	From the Canneloid Shale underlying Upper Freeport Coal, Allegheny Group, from Diamond Mine, Linton, Ohio, equivalent to Westphalian D of Europe (Carroll & Gaskill, 1978)
Microbrachis	Carroll & Gaskill, 1978	311	307	Late Moscovian	From the Nyrany location, Czech Republic (Carroll & Gaskill, 1978). See Gephyrostegus for further discussion.
Hapsidopareion	Carroll & Gaskill, 1978	280	275	Kungurian	Hennessey Formation, part of the Arroyo Formation (Carroll & Gaskill, 1978). See Varanosaurus for further discussion of the age of the Arroyo Formation.

Llistrofus	Gee et al, 2019	295	290.1	Sakmarian	Karst infills, Dolese Brothers Limestone Quarry, Sakmarian (Gee et al, 2019)
Micraroter	Carroll & Gaskill, 1978	280	275	Kungurian	Hennessey Formation, same locality as Hapsidopareion (Carroll & Gaskill, 1978). See Hapsidopareion for further discussion.
Pantylus	Carroll & Gaskill, 1978	290.1	283.5	Artkinskian	Many specimens from Moran, Putnam, Belle Plains and Clyde Formations, all part of the Wichita Group (Carroll & Gaskill, 1978). See Dimetrodon for further discussion of Wichita group.
Huskerpeton	Huttenlocker et al, 2013	298.9	295	Asselian	Mayer Farm locality, lower half of the Eskridge formation, Richardson County, Nebraska, Asselian (Huttenlocker et al, 2013)
Cardiocephalus	Carroll & Gaskill, 1978	280	275	Kungurian	There is some difficulty determining the exact horizons that specimens are from, but they are all presumed to come from the Arroyo Formation, Lower Clear Fork Group (Carroll & Gaskill, 1978). See Varanosaurus for further discussion of the age of the Arroyo formation.
Euryodus	Carroll & Gaskill, 1978	280	275	Kungurian	Arroyo Formation, Clear Fork Group (Carroll & Gaskill, 1978). See Varanosaurus.
Hyloplesion	Carroll & Gaskill, 1978	311	307	Moscovian	Known from two Middle Pennsylvanian localities, from near Pilzen, Nyrany and Tremosna, Czech Republic (Carroll & Gaskill, 1978).
Utaherpeton	Carroll et al, 1991	318.1	318.1	Bashkirian	Uppermost Manning Canyon Shale Formation. From a horizon between beds containing taxa from the North American Chesterian Age below, and Morrowan age taxa above. Thus it sits precisely at the Chesterian-Morrowan boundary, within the ICS Bashkirian stage (Carroll et al, 1991).
Carrolla	Maddin et al, 2011	295	283.5	Artinskian/Sakmarian	From the Petrol Formation, Wichita Group, Artinskian/Sakmarian (Maddin et al, 2011).
Brachydectes	Boardman II et al, 2009. Pardo et al, 2016.	298.9	292	Asselian/Sakmarian	Specimens from the Council Grove Group of Kansas, which includes the Eskridge Shale, representing the whole Asselian (Pardo et al, 2016), and the Spieser Shale, from the earliest Sakmarian
Lethiscus	Anderson et al, 2003	346.7	337	Viséan	From the Wardie Shales of Scotland, which are Viséan in age and predate the East Kirkton deposits (Anderson et al, 2003), which have an oldest age of 337Ma
Phlegethontia	Anderson, 2002	309.5	308	Moscovian	Linton, Jefferson County, Ohio. Canneloid shale below Upper Freeport Coal, Allegheny Group from Westphalian D (Anderson, 2002).

Oestocephalus	Carroll, 1998	309.5	308	Moscovian	From various locations including Nyrany, Linton, Ohio, and Mazon Creek, Illinois. These range from the Westphalian C/D boundary to the latest Westphalian D in age (Carroll, 1998)
Scincosaurus	Milner & Ruta, 2009	311	307	Moscovian	Nyrany 'Gaskohle', Czech Republic. See Gephyrostegus for age of Nyrany specimens.
Keraterpeton	Milner, 2018	319	318	Bashkirian	From the Jarrow Coal Formation, Kilkenny, Republic of Ireland, which is dated to the Langsettian (Westphalian A) in age
Diplocaulus	Harris et al, 2005	306.5	270.6	Kasimovian to Roadian	Diplocaulus is known from many localities and has an extremely broad temporal distribution, ranging, in the North American system, from the early Missourian to the end of the Leonardian (Harris et al, 2005).
Diploceraspis	Beerbower, 1963. Hembree & Bowen, 2017.	307	292.5	Kasimovian to Sakmarian	Most specimens are from the Dunkard group, but the earliest specimens come from a Conemaugh locality (Beerbower, 1963). The Dunkard group is from the Asselian and first half of the Sakmarian, while the Conemaugh group, which stretches back to the start of the Kasimovian (Hembree & Bowen, 2017)
Limnoscelis	Kennedy, 2010. Lucas et al, 2010.	305	280	Late Carboniferous-Early Permian	Specimens from El Cobre Canyon Formation, Cutler Group, El Cobre Canyon, Rio Arriba County, northern New Mexico (Kennedy, 2010). This is Virgilian-Wolfcampian age in North American Stratigraphy (Lucas et al, 2010)
Diadectes	Berman et al, 1998	281	276	Kungurian	Uppermost level of the Tambach Sandstone of the Tambach Formation (Berman et al, 1998). See Seymouria for geological details and age of this locality.
Orobates	Berman et al, 2004. Stemmerik et al, 2000.	281	276	Kungurian	Tambach formation, Upper Rotliegend, Bromacker quarry, see Seymouria for geological details of this locality.
Hylonomus	Carroll, 1964. Benton et al, 2015.	319	318	Bashkirian	All specimens come from the Joggins formation (Carroll, 1964). Carroll assigned this to the Westphalian B, but later work has suggested an age of Westphalian A (= Langsettian) for all Joggins material, with an age of 319-318Ma (Benton et al 2015).
Paleothyris	Carroll, 1969.	315.2	308	Moscovian	Morien Group, equivalent to the Westphalian C and D (Carroll, 1969).
Euconcordia	Reisz et al, 2016. Heckel & Clayton, 2006	303.7	298.9	Gzhelian	Calhoun Shale, Shawnee Group, Hamilton Quarry near Hamilton, Greenwood County, Kansas. Locality from the Virgilian series (Reisz et al, 2016) which correlates with the Gzhelian (Heckel & Clayton, 2006).

Captorhinus	Fox & Bowman, 1966.	295	283.5	Sakmarian/ Artinskian	Primarily known from Dolese Brothers Limestone Quarry Richards Spur, which is Sakmarian (see Llistrofus), and from Bally Mountain Cave Deposit, which is early Artinskian (Fox & Bowman, 1966).
Opisthodontosaurus	Reisz et al, 2015	289	289	Artinskian	From the Dolese Brothers Limestone Quarry, Oklahoma, and specifically dated to 289Ma (Reisz et al, 2015)
Archaeovenator	Reisz & Dilkes, 2003	303.7	298.9	Gzhelian	Calhoun Shale, Shawnee Group, Hamilton Quarry near Hamilton, Greenwood County, Kansas. (Reisz & Dilkes, 2003). See Euconcordia for discussion of age.
Orovenator	Ford & Benson, 2019	289	289	Artinskian	From Claystone Fissure Fills within the Dolese Brothers Limestone Quarry, Richards Spur, Oklahoma. The fills have been dated to 289Ma (Ford & Benson, 2019)
Milleretta	Gow, 1972. Gastaldo et al, 2017.	259.1	254.1	Wuchiapingian	Multiple South African localities, all outlined within Gow (1972). The ages of these localities fall within the Wuchiapingian (Gastaldo et al, 2017).
Youngina	Gow, 1975.	259.1	254.1	Wuchiapingian	Multiple South African localities, co-occuring with Milleretta, localities are outlined in Gow (1975). See Milleretta for discussion of age.
Erpetonyx	Modesto et al, 2015	303.7	298.9	Gzhelian	Cape Egmont, Prince Edward Island, Canada. The fossil is Gzhelian in age (Modesto et al, 2015).
Belebey	Reisz et al, 2007	273	268.8	Roadian	Bashkortostan and Orenburg regions, southern Russia. Upper Kaznian (Reisz et al, 2007). The Kaznian (European) overlaps with the Guadalupian, therefore the Upper Kaznian is roughly equivalent to the Roadian
Petrolacosaurus	Peabody, 1952	306.5	305	Kasimovian	Fossiliferous shales of the Garnett locality, Kansas. They are considered to be Missourian, which are part of the middle Upper Pennsylvanian, according to Peabody (1952). Missourian falls within the Kasimovian, which correlates with middle Upper Pennsylvanian stated by Peabody.
Araeoscelis	Reisz et al, 1984	290.1	283.5	Artkinskian	Collected from the Admiral Formation, Wichita Group. Other specimens have been collected from overlying strata but have not been included in the descriptions followed here, and there has been some debate as to whether they belong to the same species (Reisz et al, 1984). As such, the Admiral Formation, Whichita Group is used to denote the age, which is Artinskian (see Dimetrodon).

Varanosaurus	Berman et al, 1995. Johnnelson et al, 2013. Chaney & DeMichele, 2007.	280	275	Kungurian	Arroyo Formation, Clear Fork Group, Lower Permian, Baylor County, Texas (Berman et al, 1995). Biostragraphers agree the Clear Fork Group sits within the Leonardian stage of North America (Johhnelson et al, 2013). The Arroyo Formation is in the lower part of the Clear Fork Group (Carroll & Gaskill, 1978) which sits comfortably within the first half of the Leonardian (Chaney & DiMichele, 2007).
Edaphosaurus	Modesto, 1995	290.1	283.5	Artinskian	Geraldine bone beds in Archer County, Texas, part of the Wichita Group (Modesto, 1995). See Dimetrodon for discussion of the age.
Ianthosaurus	Reisz & Berman, 1986	306.5	305	Kasimovian	Rock Lake Member, Stanton Formation, Lansing Group, Kansas, part of the Missourian series of the Upper Pennsylvanian (Reisz & Berman, 1986). See Haptodus or Petrolacosaurus for further explanation of age
Haptodus	Laurin, 1993	306.5	305	Kasimovian	All specimens collected from the Rock Lake Shale member, Lansing group, of North American Missourian age (Laurin, 1993).
Dimetrodon	Ford & Benson, 2020. Romer & Price, 1940.	290.1	283.5	Artinskian	Several taxa are known for Dimetrodon, but most of the data studied here comes from the earlier taxa described in Romer and Price (1940), which Ford and Benson (2020) note are from the Admiral Formation of the Wichita Group, Artinskian.
Pantelosaurus	Spindler, 2016.	296	296	Asselian	Top of the youngest hard coal seam of the Döhlen formation, Saxony, Germany. Asselian in age, matching dating of 296Ma, plus or minus 3Ma (Spindler, 2016)
Varanops	Campione & Reisz, 2010	289	270.6	Artinskian to Roadian	Cacops bonebed, Arroyo formation, Clear Fork Group, Baylor County Texas, Leonardian in age. Specimens also from Mud Hill Locality, Clear Fork Group, Taylor County Texas, Leonardian in age, and from Dolese Brothers Limestone Quarry, Oklahoma, Lower Permian (Campione & Reisz, 2010). See Varanosaurus for discussion of age of Clear Fork Group.
Aerosaurus	Langston & Reisz, 1981	298.9	295	Asselian	From the Abo/Cutler formation of Rio Arriba, New Mexico (Langston & Reisz, 1981). This is deemed to be Asselian in age (Ford & Benson, 2020).
Vaughnitis	Brocklehurst et al, 2016	298.9	290.1	Asselian/Sakmarian	An age of Asselian/Sakmarian is reasonable for the Placerville area, where Vaughnitis is from (Brocklehurst et al, 2016).

Eothyris	Reisz et al, 2009. Hotton III et al, 2002.	280	280	Artinskian to early Kungarian	From the Wichita group (Reisz et al, 2009) which corresponds to the earliest Leonardian (Hotton III et al, 2002).
Echinerpeton	Mann & Paterson, 2020.	309.5	308	Westphalian D (Asturian)	Morien Group, above the Lloyd Cove Coal Seam, equivalent to the Westphalian D of Europe (Mann & Paterson, 2020)
Eocasea	Reisz & Frobisch, 2014.	302	298.9	Late Gzhelian	From Hamilton Quarry, Greenwood County, Kansas, USA, part of the Virgilian series (Reisz & Frobisch, 2014) which places Eocasea in the Late Gzhelian (Ford & Benson, 2020; supplementary information).
Casea	LeBlanc & Reisz, 2014.	280	275	Kungurian	Cacops bonebed of Baylor County, Texas (LeBlanc & Reisz, 2014). The Cacops bonebeds are part of the Arroyo formation, see Varanosaurus for further discussion.
Procynosuchus	Kemp, 1979. Viglietti, 2020.	255.2	251.9	Wuchiapingian /Changhsingian	Collected from Madumabisa Mudstones of the Middle Luangwa Valley of Zambia, regarded equivalent to the Daptocephalus zone of the Beaufort beds of the South African Karoo (Kemp, 1979). The base of the Daptocephalus zone is 255.2Ma, and overlaps with the Changhsingian epoch (Viglietti, 2020).
Caerorachis	Ruta et al, 2001	326.4	326	Pendleian stage, Serpukhovian	Most likely Upper Limestone Coal Group; Loanhead No.2 Ironstone, which matches the lithology of the specimen, although the original locality is unknown (Ruta et al, 2001)
Chroniosaurus	Clack & Klembara, 2009	259.1	254.1	Wuchiapingian	Commonest in the Poldarsa formation, from the upper Tartian stage (Clack & Klembara, 2009) which corresponds with the Wuchiapingian
Asaphestera	Carroll & Gaskill, 1978	318	315.2	Late Bashkirian	Lower Pennsylvanian, equivalent to the Westphalian B of Europe (Carroll & Gaskill, 1978)
Acanthostega	Clack, 2002	372.2	358.9	Fammenian	From the middle Fammenian, Stage 2b
Tiktaalik	Daeschler, Shubin & Jenkins, 2006	382.7	372.2	Early Frasnian	From the Fram Formation of the early and middle Frasnian stage of the Late Devonian
Eusthenopteron	Downs et al., 2018	382.7	372.2	Early Frasnian	From the Fram Formation of the early and middle Frasnian stage of the Late Devonian
Archaeothyris	Reisz et al., 1972	311	307		Westphalian D

Part 5. Synapomorphies of Selected Clades

Westlothiania + Aistopoda

Unambiguous: 7 (1 → 0), 51 (0 → 1), 99 (0 → 1), 105 (0 → 1), 121 (0 → 1), 140 (2 → 0), 178 (0 → 1), 211 (1 → 0), 224 (1 → 0), 242 (1 → 0), 309 (0 → 2).

7 Loss of dermal sculpturing
51 Prefrontal into naris
99 Posterodorsal margin of squamosal straight
105 Parietal at least 2.5 times longer than wide
121 Supratemporal strap like
140 Cultriform process extends posterior to anterior margin of sphenethmoid
178 Anterior palatine fenestra present
211 No fangs on ectopterygoid
224 No adductor crest or coronoid process on mandible
242 No lingual dentary fangs
309 Dorsal scales cover body

Crown Group Tetrapoda

Unambiguous: 122 (0 → 1), 149 (1 → 0), 152 (1 → 2), 154 (0 → 1), 176 (1 → 0), 218 (0 → 1), 220 (0 → 1), 249 (1 → 0), 253 (0 → 1), 257 (0 → 1), 319 (0 → 1), 365 (1 → 0).

122 Supratemporal contributes to skull embayment
149 Basicranial fissure absent
152 Cranial notochord absent in postembryonic individuals
154 No ossification between pina metoptica and associated taeniae
176 Vomers not separated by pterygoids
218 Quadrate dorsal process present
220 Stapes dorsal process present
249 Loss of parasymphyseal tooth plate
253 Posterodorsal process of coronoid present
257 Contact between middle coronoid and splenial
319 Cranial part of interclavicle shorter than posterior part
365 No flange on posterior edge of tibia

Total group amniotes

Unambiguous: 4 (0 → 2), 19 (0 → 1), 75 (0 → 1), 114 (0 → 1), 118 (0 → 1), 190 (2 → 1), 205 (0 → 1), 209 (1→ 0), 219 (0 → 1), 284 (0 → 1), 304 (0 → 1), 328 (1 → 0).

4 Interorbital distance longer than skull table width
19 Premaxilla contributes to concave margin of choana in more than point contact
75 Anterodorsal process of postorbital present
114 Parietal contacts tabular
118 Intertemporal does not contact squamosal

190 Palatal teeth equal in size to marginal teeth
205 Shagreen on transverse flange present
209 Ectopterygoid shorter than palatine
219 Pterygoid ramus of quadrate elongate
284 Atlas parapophyses present
304 Ribs elongate
328 Dorsal end of cleithrum unexpanded

Microsauria + Amniota

Unambiguous: 4 (2→ 1), 11 (0 → 1), 89 (1 → 0), 99 (0 → 1), 131 (0 → 1).

4 Interorbital distance equal to skull table width
11 Straight margin of posterior skull
89 Jugal extends posterior to postorbital
99 Posterior margin of squamosal straight
131 Postparietals have occipital exposure

Crown amniotes

Unambiguous: 2 (2 → 1), 7 (1 → 0), 31 (1 → 2), 46 (1 → 0), 49 (1 → 0), 79 (0 → 1), 88 (2 → 3), 110 (2 → 0), 205 (1 → 0), 206 (0 → 1), 236 (1 → 0), 346 (1 → 2).

2 Skull length .2-.29 length of trunk
7 No dermal sculpting of skull
31 Marginal teeth sharp and recurved
46 Loss of lacrimal dorsal orbital process
49 Prefrontal not 3x longer than wide
79 Free posterior margin of jugal
88 Jugal triradiate
110 Pineal foramen posterior to parietal midpoint
205 Loss of denticle shagreen on transverse process of pterygoid
206 Row of teeth on transverse flange of pterygoid
236 Dentary horizontal rather than curved
346 Radius elongate relative to humerus

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