**List of characters in Zhu et al. (2022)**

*Skeletal tissues*

1. Tessellate prismatic calcified cartilage: (0) absent; (1) present.

Choo et al. (2017), Character 1; King et al. (2017), Character 1; Castiello (2018), Character 1.

1. Prismatic calcified cartilage: (0) single layered; (1) multi-layered.

Choo et al. (2017), Character 253; King et al. (2017), Character 2; Castiello (2018), Character 2.

1. Extensive calcified cartilage: (0) absent; (1) present.

Coates et al. (2018), Character 4.

1. Perichondral bone: (0) present; (1) absent.

Choo et al. (2017), Character 2; King et al. (2017), Character 3; Castiello (2018), Character 3.

1. Extensive endochondral ossification: (0) absent; (1) present.

Choo et al. (2017), Character 3; King et al. (2017), Character 4; Castiello (2018), Character 4.

1. Three-layered exoskeleton: (0) absent; (1) present.

King et al. (2017), Character 6; Castiello (2018), Character 6.

Score changed from 0 to 1 for *Anglaspis maccoulloughi* (Keating et al., 2015).

1. Cephalic dermoskeletal bone: (0) cellular; (1) acellular.

King et al. (2017), Character 7; Castiello (2018), Character 7.

1. Perforated horizontal lamina in the sensory line canals and vascular system: (0) absent; (1) present.

King et al. (2017), Character 8; Castiello (2018), Character 8.

1. Superficial glassy layer of dermal armour: (0) absent; (1) present.

King et al. (2017), Character 18; Castiello (2018), Character 18.

1. Dentinous tissue: (0) absent; (1) present.

Choo et al. (2017), Character 4; Zhu et al. (2021), Character 9. King et al. (2017), Character 10; Castiello (2018), Character 10.

1. Dentine kind: (0) mesodentine; (1) semidentine; (2) orthodentine.

Choo et al. (2017), Character 5; King et al. (2017), Character 12; Castiello (2018), Character 12.

1. Plicidentine: (0) absent; (1) simple or generalized polyplacodont.

Choo et al. (2017), Character 137; King et al. (2017), Character 343; Castiello (2018), Character 335.

1. Enamel(oid) present on dermal bones and scales: (0) absent; (1) present.

Choo et al. (2017), Character 254; King et al. (2017), Character 15; Castiello (2018), Character 15.

1. Enamel: (0) single-layered; (1) multi-layered.

Choo et al. (2017), Character 255; King et al. (2017), Character 16; Castiello (2018), Character 16.

1. Enamel layers: (0) applied directly to one another (ganoine); (1) separated by layers of dentine.

Choo et al. (2017), Character 256; King et al. (2017), Character 17; Castiello (2018), Character 17.

1. Enamel(oid) on teeth: (0) absent; (1) present.

Choo et al. (2017), Character 284; King et al. (2017), Character 365; Castiello (2018), Character 355.

1. Cap of enameloid restricted to upper part of teeth (acrodin): (0) absent; (1) present.

Choo et al. (2017), Character 136; King et al. (2017), Character 342; Castiello (2018), Character 334; Zhu et al. (2021), Character 78.

1. Galeaspidin: (0) absent; (1) present.

King et al. (2017), Character 9; Castiello (2018), Character 9.

1. Extensive pore canal network: (0) absent; (1) present.

Choo et al. (2017), Character 257; King et al. (2017), Character 5; Castiello (2018), Character 5.

1. Resorption and redeposition of odontodes: (0) lacking or partially developed; (1) developed.

Choo et al. (2017), Character 157; King et al. (2017), Character 14; Castiello (2018), Character 14.

1. Generations of odontodes: (0) buried; (1) areally growing; (2) resorbed.

Zhu et al. (2021), Character 17.

Score changed from 1 to – for Galeaspida, from 2 to – for *Eusthenopteron*.

1. Enamel and pore canals: (0) enamel absent from inner surface of pores; (1) enamel lines portions of pore canal.

Zhu et al. (2021), Character 232?

1. Relative size of cosmine pores: (0) small; (1) large.

King et al. (2017), Character 270; Castiello (2018), Character 264.

1. Rostral tubuli: (0) absent; (1) present.

Choo et al. (2017), Character 158; King et al. (2017), Character 67; Castiello (2018), Character 69.

1. Bone cell lacunae in body scale bases: (0) present; (1) absent.

Choo et al. (2017), Character 259. King et al. (2017), Character 11; Castiello (2018), Character 11.

Score changed from 0 to 1 for Galeaspida.

1. Main dentinous tissue forming fin spine: (0) osteodentine; (1) orthodentine.

Choo et al. (2017), Character 260; King et al. (2017), Character 13; Castiello (2018), Character 13.

*Squamation & related structures*

1. Lepidotrichia or lepidotrichia-like scale alignment: (0) present; (1) absent.

Choo et al. (2017), Character 6.

1. Differentiated lepidotrichia: (0) absent; (1) present.

Choo et al. (2017), Character 261; King et al. (2017), Character 469; Castiello (2018), Character 458.

1. Epichordal lepidotrichia in caudal fin: (0) absent; (1) present.

Choo et al. (2017), Character 140; King et al. (2017), Character 470; Castiello (2018), Character 459.

1. Barbed lepidotrichial segments: (0) absent; (1) present.

Zhu et al. (2021), Character 263.

1. Fringing fulcra: (0) absent; (1) present.

Choo et al. (2017), Character 252; King et al. (2017), Character 467; Castiello (2018), Character 456.

1. Scute-like ridge scales (basal fulcra): (0) absent; (1) present.

Choo et al. (2017), Character 264; King et al. (2017), Character 471; Castiello (2018), Character 460.

1. Flank scale alignment: (0) vertical rows; (1) oblique rows or hexagonal/rhombic packing; (2) disorganised.

Choo et al. (2017), Character 13; King et al. (2017), Character 491; Castiello (2018), Character 481.

1. Scales: (0) macromeric; (1) micromeric.

King et al. (2017), Character 496; Castiello (2018), Character 485

1. Body scale growth pattern: (0) monodontode (monocuspid); (1) polyodontode (multicuspid).

Choo et al. (2017), Character 7; Coates et al. (2018), Character 9; King et al. (2017), Character 485; Castiello (2018), Character 474. The coding of *Helodus* is changed from 1 to 0 (Coates et al., 2018).

1. Body scale growth concentric: (0) absent; (1) present.

Choo et al. (2017), Character 8; King et al. (2017), Character 486; Castiello (2018), Character 475.

1. Body scales with peg-and-socket articulation: (0) absent; (1) present.

Choo et al. (2017), Character 9; King et al. (2017), Character 487; Castiello (2018), Character 476.

1. Peg on rhomboid scale: (0) longer than wide (narrow); (1) wider than long (broad).

Choo et al. (2017), Character 138; King et al. (2017), Character 492; Castiello (2018), Character 477.

1. Body scale profile: (0) distinct crown and base demarcated by a constriction (neck); (1) flattened.

Choo et al. (2017), Character 10; King et al. (2017), Character 488; Castiello (2018), Character 478.

1. Body scales with bulging base: (0) absent; (1) present.

Choo et al. (2017), Character 11; King et al. (2017), Character 489; Castiello (2018), Character 479.

1. Body scales with flattened base: (0) absent; (1) present.

Choo et al. (2017), Character 12; King et al. (2017), Character 490; Castiello (2018), Character 480. The character states in Brazeau (2009, Character 13) were reversed.

1. Relationship of crown and base of isolated trunk scale: (0) crown fully covering the base; (1) crown sitting on the bony base, with an exposed depressed field overlapped by adjacent scale in articulation.

Choo et al. (2017), Character 336.

1. Profile of scales with constriction between crown and base: (0) neck similar in width to crown; (1) neck greatly constricted, resulting in anvil-like shape.

Choo et al. (2017), Character 262; King et al. (2017), Character 494; Castiello (2018), Character 483.

1. Body scales with basal canal or open basal vascular cavity (basal pores in scales): (0) absent; (1) present.

Choo et al. (2017), Character 263; Coates et al. (2018), Character 15; King et al. (2017), Character 495; Castiello (2018), Character 484.

1. Neck canal: (0) absent; (1) present.

Coates et al. (2018), Character 16.

1. Keel of scale: (0) absent; (1) present.

Cui et al. (2019), Character 343.

1. Posterior ledge (or secondary keel) of scale: (0) absent; (1) weak; (2) developed.

Cui et al. (2019), Character 344.

1. Anteroventral process of scale: (0) absent; (1) present.

Cui et al. (2019), Character 345.

1. Ventral process of scale: (0) present; (1) absent.

Cui et al. (2019), Character 346.

1. Anterodorsal process on scale: (0) absent; (1) present.

Choo et al. (2017), Character 139; King et al. (2017), Character 493; Castiello (2018), Character 482.

1. Anterodorsal process and peg: (0) separated; (1) confluent.
2. Sensory line canal of body: (0) passes between or beneath scales; (1) passes over scales and/or is partially enclosed or surrounded by scales; (2) perforates and passes through scales.

Choo et al. (2017), Character 14; Coates et al. (2018), Character 17; Dearden et al. (2019), Character 17; King et al. (2017), Character 324; Castiello (2018), Character 316.

1. Sensory line canal of head: (0) passes between or beneath scales; (1) passes over scales and/or is partially enclosed or surrounded by scales; (2) perforates and passes through scales.

Choo et al. (2017), Character 14; Coates et al. (2018), Character 17; Dearden et al. (2019), Character 18.

1. Longitudinal scale alignment in fin webs: (0) present; (1) absent.

Zhu et al. (2021), Character 13; King et al. (2017), Character 468; Castiello (2018), Character 457.

1. Sensory line scales/plates on head: (0) unspecialized; (1) apposed growth; (2) paralleling canal; (3) semicylindrical C-shaped ring scales.

Zhu et al. (2021), Character 59.

*Cranial dermal skeleton*

1. Dermal ornamentation: (0) smooth; (1) parallel, vermiform ridges; (2) concentric ridges; (3) tuberculate.

Choo et al. (2017), Character 265; King et al. (2017), Character 205; Castiello (2018), Character 204.

1. Sensory line network: (0) preserved as open grooves; (1) pass through canals enclosed within dermal bones.

Choo et al. (2017), Character 15; King et al. (2017), Character 283; Castiello (2018), Character 276.

1. Sensory canals/grooves: (0) contained within the thickness of dermal bones; (1) contained in prominent ridges on visceral surface of bone.

Choo et al. (2017), Character 266; King et al. (2017), Character 301; Castiello (2018), Character 292.

1. Dermal skull roof: (0) includes large dermal plates; (1) consists of undifferentiated plates or tesserae; (2) include both large dermal plates and tesserae.

Davis et al. (2012), Character 18; Choo et al. (2017), Character 17; King et al. (2017), Character 151; Castiello (2018), Character 150.

Score changed from 0 to 1 for *Kawichthys*.

1. Tesserae morphology: (0) large interlocking polygonal plates: (1) microsquamose, not larger than body tesserae.

Choo et al. (2017), Character 18; King et al. (2017), Character 152; Castiello (2018), Character 151.

1. Extent of dermatocranial cover: (0) complete; (1) incomplete (scale-free and elsewhere).

Choo et al. (2017), Character 19; King et al. (2017), Character 153; Castiello (2018), Character 152.

1. Unpaired median skull roofing bone in contact with unpaired plate bearing pineal eminence or foramen: (0) absent; (1) present.

Castiello (2018), Character 189.

1. Median rostral extension of the headshield: (0) absent; (1) present.

King et al. (2017), Character 218; Castiello (2018), Character 217.

1. Lateral fields: (0) absent; (1) present.

King et al. (2017), Character 219; Castiello (2018), Character 218

1. Division of lateral fields: (0) absent; (1) divided once; (2) divided twice.

King et al. (2017), Character 220; Castiello (2018), Character 219

1. Lateral fields extend posterior to pectoral sinus: (0) absent; (1) present.

King et al. (2017), Character 221; Castiello (2018), Character 220

1. Lateral fields extend onto cornua: (0) absent; (1) present.

King et al. (2017), Character 222; Castiello (2018), Character 221

1. Median fields: (0) absent; (1) present.

King et al. (2017), Character 223; Castiello (2018), Character 222

1. Median field separation from pineal plate or foramen: (0) absent; (1) present.

King et al. (2017), Character 224; Castiello (2018), Character 223

1. Median dorsal opening: (0) absent; (1) present.

King et al. (2017), Character 226; Castiello (2018), Character 225

1. Cornual extensions: (0) absent; (1) present.

King et al. (2017), Character 229; Castiello (2018), Character 228

1. Corners: (0) absent; (1) present.

Castiello (2018), Character 229

1. Fused scale rows on posterior of headshield: (0) absent; (1) present.

King et al. (2017), Character 230; Castiello (2018), Character 230

1. Dorsal spinal process of headshield: (0) absent; (1) present.

King et al. (2017), Character 231; Castiello (2018), Character 231

1. Oralobranchial covering: (0) minute scales; (1) tesserae (2); dermal plates; (3) one or two massive dermal plates.

King et al. (2017), Character 232; Castiello (2018), Character 232

1. Shape of median dorsal opening: (0) transverse slit-like; (1) oval-like (2); slender longitudinal oval.

King et al. (2017), Character 233; Castiello (2018), Character 234

1. Spines on corners: (0) absent; (1) present.

King et al. (2017), Character 234; Castiello (2018), Character 233

1. Headshield enclosed posteriorly behind oralobranchial chamber: (0) no; (1) yes.

King et al. (2017), Character 235; Castiello (2018), Character 235

1. Enlarged tubercles form symmetrical pattern on posterior part of head shield: (0) absent; (1) present.

King et al. (2017), Character 236; Castiello (2018), Character 236

1. T-shaped rostral plate: (0) absent; (1) present.

King et al. (2017), Character 237; Castiello (2018), Character 237

1. Single median element carrying the central, middle and posterior pit line: (0) absent; (1) present.

King et al. (2017), Character 238; Castiello (2018), Character 238

1. Postnuchal plates: (0) absent; (1) present.

King et al. (2017), Character 239; Castiello (2018), Character 239

Score changed from 1 to 0 for *Eurycaraspis*, 1 to ? for *Paucipetalichthys*, ? to 0 for *Qilinyu* as for antiarchs.

1. Cutaneous sensory organ on suborbital plate: (0) absent; (1) present.

King et al. (2017), Character 240; Castiello (2018), Character 240

1. Cutaneous sensory organ on postsuborbital plate: (0) absent; (1) present.

King et al. (2017), Character 241; Castiello (2018), Character 241

1. Cutaneous sensory organ on skull roof posterior to orbits: (0) absent; (1) present.

King et al. (2017), Character 242; Castiello (2018), Character 242

1. Sclerotic ring incorporated into skull roof: (0) absent; (1) present.

King et al. (2017), Character 244; Castiello (2018), Character 243

1. Rostrocaudal groove on the inner surface of the premedian plate: (0) absent; (1) present.

King et al. (2017), Character 245; Castiello (2018), Character 244

1. Preorbital depression: (0) absent; (1) present.

King et al. (2017), Character 246; Castiello (2018), Character 245

1. Preorbital recess: (0) absent; (1) present.

Zhu et al. (2016), Character 342; King et al. (2017), Character 247; Castiello (2018), Character 246; Zhu et al. (2021), Character 311.

Score changed from 0 to 1 for *Minicrania lirouyii* (Zhu and Janvier, 1996).

1. Preorbital recess: (0) restricted to premedian plate; (1) extends onto lateral plates.

King et al. (2017), Character 248; Castiello (2018), Character 247.

1. Submarginal articulation: (0) absent; (1) present.

King et al. (2017), Character 250; Castiello (2018), Character 249.

1. Prelateral plate: (0) absent; (1) present.

King et al. (2017), Character 251; Castiello (2018), Character 250.

1. Posterior descending lamina of skull roof: (0) absent; (1) present.

King et al. (2017), Character 252; Castiello (2018), Character 251.

1. Mesial lamina on the internal surface of marginal plate: (0) absent; (1) present.

King et al. (2017), Character 254; Castiello (2018), Character 252.

1. Nostrils enclosed in dermal skull roof: (0) yes; (1) no.

King et al. (2017), Character 255; Castiello (2018), Character 253.

1. Lacrimal: (0) absent; (1) present.

King et al. (2017), Character 257; Castiello (2018), Character 254.

1. Pineal and rostral: (0) contact; (1) separated.

King et al. (2017), Character 258; Castiello (2018), Character 255.

1. Snout region fragmented into mosaic of small plates: (0) no; (1) yes.

King et al. (2017), Character 259; Castiello (2018), Character 256.

1. B-bone: (0) absent; (1) present.

King et al. (2017), Character 261; Castiello (2018), Character 258.

1. Series of bones lateral to supratemporal (postmarginal plate in placoderms): (0) absent; (1) single bone; (2) two bones.

King et al. (2017), Character 263; Castiello (2018), Character 260.

Score changed from 1 to 0 for *Romundina*.

1. Pore clusters: (0) absent; (1) present.

King et al. (2017), Character 267; Castiello (2018), Character 261.

1. Prerostral plate: (0) absent; (1) present.

King et al. (2017), Character 269; Castiello (2018), Character 263.

1. Interparietal: (0) absent; (1) present.

King et al. (2017), Character 271; Castiello (2018), Character 265.

1. Supratemporal (marginal) in contact with postparietal (central): (0) absent; (1) present.

King et al. (2017), Character 273; Castiello (2018), Character 267.

1. Supratemporal (marginal) contact with nasal (postnasal): (0) absent; (1) present.

King et al. (2017), Character 274; Castiello (2018), Character 268.

1. Quadratojugal: (0) present; (1) absent.

King et al. (2017), Character 276; Castiello (2018), Character 270.

*Buchanosteus* *confertituberculatus* is coded 1 (Young, 1979).

1. Accessory operculum: (0) absent; (1) present.

King et al. (2017), Character 278; Castiello (2018), Character 272.

1. Dermal bone (sarcopterygian postorbital) between jugal (suborbital) and intertemporal (postorbital): (0) absent; (1) present.

King et al. (2017), Character 279; Castiello (2018), Character 273.

1. Lacrimal notch: (0) absent; (1) present.

King et al. (2017), Character 280; Castiello (2018), Character 274.

1. Orbital process of maxilla: (0) absent; (1) present.

King et al. (2017), Character 282; Castiello (2018), Character 275.

1. Dermal cranial joint at level of sphenoid-otic junction: (0) absent; (1) present.

Choo et al. (2017), Character 141; King et al. (2017), Character 170; Castiello (2018), Character 168.

1. Posterior nostril: (0) associated with orbit; (1) not associated with orbit.

Choo et al. (2017), Character 142; King et al. (2017), Character 171; Castiello (2018), Character 169.

1. Posterior nostril: (0) external; (1) palatal.

Choo et al. (2017), Character 332.

1. Posterior nostril in external position: (0) far from jaw margin; (1) at or close to jaw margin.

Choo et al. (2017), Character 163; King et al. (2017), Character 181; Castiello (2018), Character 178.

1. Choana: (0) absent; (1) present.

King et al. (2017), Character 260; Castiello (2018), Character 257.

1. Lacrimal posteriorly enclosing posterior nostril: (0) absent; (1) present.

Choo et al. (2017), Character 179; King et al. (2017), Character 194; Castiello (2018), Character 193.

1. Premaxilla contributes to posterior nostril: (0) absent; (1) present.

King et al. (2017), Character 272; Castiello (2018), Character 266.

1. Position of anterior nostril: (0) facial; (1) at oral margin.

Zhu et al. (2021), Character 255.

1. Number of nasals: (0) many; (1) one or two.

Choo et al. (2017), Character 160; King et al. (2017), Character 178; Castiello (2018), Character 175.

1. Mesial margin of nasal: (0) not notched; (1) notched.

Choo et al. (2017), Character 161; King et al. (2017), Character 179; Castiello (2018), Character 176.

The coding for *Cheirolepis* was changed to ‘1’, following Coates et al. (2018, Character 29). Unlike Coates et al. (2018), the coding for *Mimipiscis* and *Moythomasia* was retained as ‘1’.

1. Dermintermedial process: (0) absent; (1) present.

Choo et al. (2017), Character 162; King et al. (2017), Character 180; Castiello (2018), Character 177.

The process seems present in *Ligulalepis*. The presence should be a plesiomorphy for osteichthyans.

1. Extended preorbital region between eyes and nasal capsule: (0) absent; (1) present.

King et al. (2017), Character 22; Castiello (2018), Character 22.

1. Orbit dorsal or facing dorsolaterally: (0) present; (1) absent.

Castiello (2018), Character 29.

1. Orbits, surrounded laterally by endocranium: (0) absent; (1) partially surrounded; (2) surrounded.

Castiello (2018), Character 30.

1. Supraorbital (sensu Cloutier and Ahlberg 1996, including posterior tectal of Jarvik): (0) absent; (1) present.

Choo et al. (2017), Character 164; King et al. (2017), Character 182; Castiello (2018), Character 179.

1. Number of supraorbitals: (0) one; (1) two; (2) many.

King et al. (2017), Character 262; Castiello (2018), Character 259.

1. Supraorbital, preorbital and nasal: (0) unfused; (1) fused.

Choo et al. (2017), Character 165; King et al. (2017), Character 183; Castiello (2018), Character 180.

1. Tectal (sensu Cloutier and Ahlberg 1996, not counting the posterior tectal of Jarvik): (0) absent; (1) present.

Choo et al. (2017), Character 166; King et al. (2017), Character 184; Castiello (2018), Character 181l.

1. Pineal opening in braincase: (0) absent; (1) present.

King et al. (2017), Character 115; Castiello (2018), Character 116.

1. Pineal opening perforation in dermal skull roof: (0) present; (1) absent.

Davis et al. (2012), Character 25; Choo et al. (2017), Character 24; King et al. (2017), Character 159; Castiello (2018), Character 117.

1. Pineal eminence (in taxa lacking pineal foramen): (0) absent; (1) present.

Zhu et al. (2021), Character 233.

1. Location of pineal foramen/eminence: (0) level with posterior margin of orbits; (1) well posterior of orbits.

Choo et al. (2017), Character 168; King et al. (2017), Character 186; Castiello (2018), Character 183.

1. Opening in dermal skull roof for spiracular bounded by bones carrying otic canal: (0) absent; (1) present.

Choo et al. (2017), Character 327; King et al. (2017), Character 188; Castiello (2018), Character 186.

1. Dermal plate associated with pineal eminence or foramen: (0) contributes to orbital margin; (1) plate bordered laterally by skull roofing bones.

Choo et al. (2017), Character 270; King et al. (2017), Character 208; Castiello (2018), Character 207.

1. Skull roof with broad supraorbital vaults: (0) absent; (1) present.

Dennis and Miles, 1981, Character 16; Choo et al. (2017), Character 271; King et al. (2017), Character 200; Castiello (2018), Character 208.

1. Parietals (preorbitals of placoderms): (0) absent; (1) present.

Choo et al. (2017), Character 169; Clement et al. (2018), Character 279.

1. Condition of parietals/preorbitals: (0) do not meet in midline; (1) meet in midline; (2) single midline bone.

Clement et al. (2018), Character 280.

1. Parietals (preorbitals of placoderms) surround pineal foramen or eminence: (0) yes; (1) no.

King et al. (2017), Character 187; Castiello (2018), Character 184.

1. Postparietals (centrals of placoderms): (0) absent; (1) present.

Clement et al. (2018), Character 277.

1. Condition of postparietals/centrals: (0) do not meet in midline; (1) meet in midline; (2) single midline bone.

Clement et al. (2018), Character 278.

1. Suture between paired skull roofing bones: (0) straight; (1) sinusoidal.

Choo et al. (2017), Character 274; King et al. (2017), Character 210; Castiello (2018), Character 209.

1. Large unpaired median skull roofing bone anterior to the level of nasal capsules (premedian plate): (0) absent; (1) present.

Choo et al. (2017), Character 159; King et al. (2017), Character 177; Castiello (2018), Character 174.

1. Position of premedian plate: (0) dorsal; (1) ventral.
2. Postnasal plate: (0) absent; (1) present.

Zhu et al. (2016), Character 341; Zhu et al. (2021), Character 310.

1. Postmarginal plate: (0) absent; (1) present.

Zhu et al. (2016), Character 346; Zhu et al. (2021), Character 313.

1. Obstantic margin of skull roof: (0) long; (1) short.

Zhu et al. (2016), Character 347; Zhu et al. (2021), Character 314.

1. Large unpaired median bone contributing to posterior margin of skull roof (nuchal plate): (0) absent; (1) present.

Choo et al. (2017), Character 172.

1. Nuchal plate: (0) without orbital facets; (1) with orbital facets.

Castiello (2018), Character 248.

1. Nuchal reaching or almost reaching orbital margin: (0) absent; (1) present.

Zhu et al. (2016), Character 345; Zhu et al. (2021), Character 312.

1. Paired pits on ventral surface of nuchal or median extrascapular plate: (0) absent; (1) present.

Choo et al. (2017), Character 276; King et al. (2017), Character 212; Castiello (2018), Character 211.

1. Contact of nuchal or centronuchal or median extrascapular plate with paired preorbital or parietal plates: (0) absent; (1) present.

Choo et al. (2017), Character 173.

1. Number of marginal bones alongside paired median skull roofing bones over the otico-occipital division of braincase: (0) single; (1) two or more.

Choo et al. (2017), Character 143; King et al. (2017), Character 172; Castiello (2018), Character 170; Zhu et al. (2021), Character 46.

1. Lateral plate: (0) absent; (1) present.

Choo et al. (2017), Character 167; King et al. (2017), Character 185; Castiello (2018), Character 182.

1. Paranuchal number: (0) one pair; (1) two pairs.

Choo et al. (2017), Character 171; King et al. (2017), Character 189; Castiello (2018), Character 187.

1. Median paranuchal plate: (0) absent; (1) present.

We exclude the median paranuchal plate from the parachal series (Character 154), which runs along the main lateral line. Paired median paranuchals are present in some acanthothoracids, e.g., *Romundina*, *Arabosteus* (Olive et al., 2011) and *Sudaspis* (Vaškaninová and Ahlberg, 2017).

1. Posterior process of the paranuchal plate behind the nuchal plate (dorsal face): (0) absent; (1) present.

Choo et al. (2017), Character 174.

1. Medial processes of paranuchal wrapping posterolateral corners of nuchal plate: (0) absent; (1) present; (2) paranuchals precluded from nuchal by central or median paranuchal.

Choo et al. (2017), Character 275; King et al. (2017), Character 211; Castiello (2018), Character 210.

1. Posterior projection on posterior paranuchal plate: (0) absent; (1) present

Castiello (2018), Character 188; Castiello (2018), Character 188.

1. Canal-bearing bone of skull roof extends far past posterior margin of parietals: (0) no; (1) yes.

Choo et al. (2017), Character 325; Castiello (2018), Character 185

1. Extratemporal: absent (0), present (1).
2. Westoll-lines: (0) absent; (1) present.

Zhu et al. (2021), Character 237; King et al. (2017), Character 268; Castiello 2018 Character 262.

1. Anteriorly directed adductor fossae between neurocranium and skull roof: (0) absent; (1) present.

Zhu et al. (2021), Character 250.

1. Anterior pit line of dermal skull roof: (0) absent; (1) present.

Choo et al. (2017), Character 267; King et al. (2017), Character 302; Castiello (2018), Character 293.

1. Position of anterior pit-line: (0) on paired median skull roofing bones over the otico-occipital division of braincase; (1) on paired median skull roofing bones over the sphenoid division of braincase.

Choo et al. (2017), Character 189; King et al. (2017), Character 287; Castiello (2018), Character 279.

1. Middle and posterior pit-lines on postparietal: (0) posteriorly situated; (1) mesially situated.

Choo et al. (2017), Character 190; King et al. (2017), Character 288; Castiello (2018), Character 280.

1. Position of middle and posterior pit lines: (0) close to midline; (1) near the central portion of each postparietal.

Choo et al. (2017), Character 191; King et al. (2017), Character 289; Castiello (2018), Character 281.

1. Junction of posterior pitline and main lateral line: (0) far in front of posterior margin of skull roof; (1) close to posterior margin of skull roof.

Choo et al. (2017), Character 175.

1. Ethmoid commissure: (0) absent; (1) present.

Castiello (2018), Character 311.

1. Ethmoid commissure fused into midline canal: (0) absent; (1) present.

King et al. (2017), Character 320; Castiello (2018), Character 312.

1. Course of ethmoid commissure: (0) middle portion through median rostral; (1) sutural course; (2) through bone center of premaxillary.

Choo et al. (2017), Character 188; King et al. (2017), Character 286; Castiello (2018), Character 278.

1. Infraorbital canal follows premaxillary suture: (0) no; (1) yes.

Choo et al. (2017), Character 198; King et al. (2017), Character 296; Castiello (2018), Character 287.

1. Postmarginal canal: (0) absent; (1) present.

King et al. (2017), Character 315; Castiello (2018), Character 306.

1. Postmarginal line issued from main lateral line: (0) on marginal or supratemporal; (1) on anterior paranuchal or tabular.

Zhu et al. (2016), Character 349; Zhu et al. (2021), Character 315.

1. Central sensory line: (0) absent; (1) present.

Zhu et al. (2016), Character 350; Zhu et al. (2021), Character 316; King et al. (2017), Character 312; Castiello (2018), Character 303.

1. Supraorbital sensory canals: (0) absent; (1) present.

King et al. (2017), Character 307; Castiello (2018), Character 299.

1. Course of supraorbital canal: (0) between anterior and posterior nostrils; (1) anterior to both nostrils.

Choo et al. (2017), Character 192; King et al. (2017), Character 290; Castiello (2018), Character 282.

1. Course of supraorbital canal: (0) straight; (1) lyre-shaped.

Choo et al. (2017), Character 193; King et al. (2017), Character 291; Castiello (2018), Character 283.

1. Posterior end of supraorbital canal: (0) in postparietal (central); (1) in parietal (preorbital); (2) in intertemporal; (3) in nuchal plate; (4) in postpineal plate.

Choo et al. (2017), Character 194.

1. Posteriorly converging supraorbital canals: (0) absent; (1) present.
2. Supraorbital canals and posterior pitlines convergence: (0) absent; (1) converge without contact; (2) converge with contact.

Long et al. (2015), Character 256; Choo et al. (2017), Character 248; King et al. (2017), Character 300; Castiello (2018), Character 291.

The character “median commissure between supraorbital sensory lines: (0) absent; (1) present” (Choo et al., 2017, Character 272; Giles et al., 2015c, Character 45) is deleted due to its overlap with the current state 2.

1. Contact between otic and supraorbital canals: (0) not in contact; (1) in contact.

Choo et al. (2017), Character 195; King et al. (2017), Character 293; Castiello (2018), Character 284.

1. Contact of supraorbital and infraorbital canals: (0) in contact rostrally; (1) not in contact rostrally.

Choo et al. (2017), Character 196; King et al. (2017), Character 294; Castiello (2018), Character 285.

1. Otic canal: (0) runs through skull roof; (1) follows edge of skull roof.

Choo et al. (2017), Character 197; King et al. (2017), Character 295; Castiello (2018), Character 286.

1. Otic canal extends through postparietals (central): (0) absent; (1) present.

Choo et al. (2017), Character 273; King et al. (2017), Character 303; Castiello (2018), Character 294.

1. Jugal portion of infraorbital canal joins supramaxillary canal: (0) present; (1) absent.

Choo et al. (2017), Character 16; King et al. (2017), Character 284; Castiello (2018), Character 277.

1. Infra-orbital sensory line: (0) crosses lateral field; (1) does not cross lateral field.

Castiello (2018), Character 295; King et al. (2017), Character 304.

1. Festooned pattern of sensory canals: (0) absent; (1) present.

King et al. (2017), Character 305; Castiello (2018), Character 296.

1. Median transverse canals: (0) two or more; (1) one; (2) absent.

Castiello (2018), Character 297; Zhu and Gai (2006), Character 30.

We added the third state (“absent”) to describe the condition in jawed vertebrates.

1. Multiply branched sensory canal system associated with the posterior end of the supraorbital canal: (0) absent; (1) present.

King et al. (2017), Character 306; Castiello (2018), Character 298

In the present dataset, the character is only present in *Wenshanaspis*.

1. Branching end of lateral transverse canals: (0) absent; (1) present.

King et al. (2017), Character 308; Castiello (2018), Character 300.

In the present dataset, the character is only present in *Wenshanaspis*.

1. Median dorsal canal: (0) absent; (1) present.

King et al. (2017), Character 310; Castiello (2018), Character 301.

Score changed from 0/1 to 1 for *Eugaleaspis changi*; 0 to ? for *Shuyu zhejiangensis*.

1. Infraorbital and otic sensory line grooves run along mesial margin of marginal plate: (0) no; (1) yes.

King et al. (2017), Character 311; Castiello (2018), Character 302.

1. Semicircular pit line: (0) absent; (1) present.

King et al. (2017), Character 313; Castiello (2018), Character 304.

In the present dataset, the character is only present in *Bothriolepis*.

1. Horizontal sensory line canal on cheek: (0) absent; (1) present.

King et al. (2017), Character 314; Castiello (2018), Character 305.

1. Preopercular canal: (0) absent; (1) present.

King et al. (2017), Character 316; Castiello (2018), Character 307.

1. Preopercular canal meets otic canal: (0) absent; (1) present.

King et al. (2017), Character 317; Castiello (2018), Character 308.

1. Supraoral canal: (0) absent; (1) present.

King et al. (2017), Character 318; Castiello (2018), Character 309.

1. Extension of otic canal beyond infraorbital canal ("P" canal): (0) absent; (1) present.

King et al. (2017), Character 319; Castiello (2018), Character 310.

1. Posterior pitline and postmarginal canal in contact: (0) absent; (1) present.

King et al. (2017), Character 321; Castiello (2018), Character 313.

In the present dataset, the character is only present in *Entelognathus*.

1. Supraorbital canal joins infraorbital canal: (0) anterior to supraoral canal; (1) posterior to supraoral canal.

King et al. (2017), Character 322; Castiello (2018), Character 314.

1. Sensory line commissure across extrascapular bones (nuchal and paranuchal): (0) absent; (1) present.

King et al. (2017), Character 323; Castiello (2018), Character 315.

1. Sensory canal or pit-line associated with maxilla: (0) absent; (1) present.

Choo et al. (2017), Character 199; King et al. (2017), Character 297; Castiello (2018), Character 288.

1. Endolymphatic ducts open in dermal skull roof: (0) present; (1) absent.

Choo et al. (2017), Character 20; King et al. (2017), Character 154; Castiello (2018), Character 153.

1. External endolymphatic duct openings’ location in relation to median field: (0) internal; (1) external.

Castiello (2018), Character 224.

1. Endolymphatic ducts with oblique course through dermal skull bones: (0) absent; (1) present.

Choo et al. (2017), Character 21; King et al. (2017), Character 155; Castiello (2018), Character 154.

1. Endolymphatic duct relationship to median skull roof bone (i.e. nuchal plate): (0) within median bone; (1) on bones flanking the median bone (e.g. paranuchals).

Choo et al. (2017), Character 269; King et al. (2017), Character 207; Castiello (2018), Character 206.

1. Sclerotic ring: (0) absent; (1) present.

Choo et al. (2017), Character 277; King et al. (2017), Character 213; Castiello (2018), Character 212.

1. Number of sclerotic plates: (0) four or less; (1) more than four.

Choo et al. (2017), Character 241; King et al. (2017), Character 204; Castiello (2018), Character 203.

1. Number of extrascapulars: (0) uneven; (1) paired.

Choo et al. (2017), Character 176; King et al. (2017), Character 191; Castiello (2018), Character 190.

1. Number of paired extrascapulars: (0) one pair; (1) two pairs.

King et al. (2017), Character 277; Castiello (2018), Character 271.

1. Consolidated cheek plates: (0) absent; (1) present.

Choo et al. (2017), Character 23; King et al. (2017), Character 157; Castiello (2018), Character 156.

1. Foramina (similar to infradentary foramina) on cheek bones: (0) absent; (1) present.

Choo et al. (2017), Character 178; King et al. (2017), Character 193; Castiello (2018), Character 192.

1. Most posterior major bone of cheek bearing preopercular canal (preopercular) extending forward, close to orbit: (0) absent; (1) present.

Choo et al. (2017), Character 180; King et al. (2017), Character 195; Castiello (2018), Character 194.

1. Number of cheek bones bearing preopercular canal posterior to jugal: (0) one; (1) two.

Choo et al. (2017), Character 181; King et al. (2017), Character 196; Castiello (2018), Character 195.

1. Bone bearing both quadratojugal pit-line and preopercular canal: (0) absent; (1) present.

Choo et al. (2017), Character 182; King et al. (2017), Character 197; Castiello (2018), Character 196.

1. Anterior portion of preopercular canal: (0) present; (1) absent.

Choo et al. (2017), Character 200.

1. Vertical canal associated with preopercular/suborbital canal: (0) absent; (1) present.

Choo et al. (2017), Character 258.

1. Cheek plate: (0) undivided; (1) divided (i.e., squamosal and preopercular).

Choo et al. (2017), Character 278; King et al. (2017), Character 214; Castiello (2018), Character 213.

1. Subsquamosals in taxa with divided cheek: (0) absent; (1) present.

Choo et al. (2017), Character 279; King et al. (2017), Character 215; Castiello (2018), Character 214.

1. Preopercular shape: (0) rhombic; (1) bar-shaped.

Choo et al. (2017), Character 280; King et al. (2017), Character 216; Castiello (2018), Character 215.

1. Preoperculosubmandibular: (0) absent; (1) present.

Choo et al. (2017), Character 328.

1. Dermohyal: (0) absent; (1) present.

Choo et al. (2017), Character 183; King et al. (2017), Character 198; Castiello (2018), Character 197.

Gardiner and Schaeffer (1989, ch.A2) and Coates (1998, ch.A2) defined this character as a dermohyal covering the head of the hyomandibular which notches the supratemporal or the dermosphenotic (Cloutier and Arratia, 2004).

1. Enlarged postorbital tesserae separated from orbital series: (0) absent; (1) present.

Choo et al. (2017), Character 25; King et al. (2017), Character 159; Castiello (2018), Character 157.

1. Bony hyoidean gill-cover series (branchiostegals): (0) absent; (1) present.

Choo et al. (2017), Character 26; King et al. (2017), Character 160; Castiello (2018), Character 158.

1. Branchiostegal plate series along ventral margin of lower jaw: (0) absent; (1) present.

Choo et al. (2017), Character 27; King et al. (2017), Character 161; Castiello (2018), Character 159.

1. Branchiostegal ossifications: (0) plate-like; (1) narrow and ribbon-like.

Choo et al. (2017), Character 28; King et al. (2017), Character 162; Castiello (2018), Character 160.

1. Branchiostegal ossifications: (0) ornamented; (1) unornamented.

Choo et al. (2017), Character 29; King et al. (2017), Character 163; Castiello (2018), Character 161.

1. Imbricated branchiostegal ossifications: (0) absent; (1) present.

Choo et al. (2017), Character 30; King et al. (2017), Character 164; Castiello (2018), Character 162.

1. Opercular flap/gill slits: (0) complete or partial; (1) separate gill covers and gill slits.

Choo et al. (2017), Character 31. Dearden et al. (2019), Character 73; King et al. (2017), Character 165; Castiello (2018), Character 163.

1. Opercular (submarginal) ossification: (0) absent; (1) present.

Choo et al. (2017), Character 32.

1. Shape of opercular (submarginal) ossification: (0) broad plate that tapers towards its proximal end; (1) narrow, rod-shaped.

Choo et al. (2017), Character 33; King et al. (2017), Character 166; Castiello (2018), Character 164.

1. Ventral lamina of opercular (submarginal) ossification: (0) absent; (1) present.

Zhu et al. (2016), Character 355; Zhu et al. (2021), Character 317.

1. Ventral lamina of suborbital (jugal): (0) absent; (1) present.

Zhu et al. (2016), Character 356) Zhu et al. (2021), Character 318.

1. Notch in anterior margin of jugal: (0) absent; (1) present

King et al. (2017), Character 275; Castiello (2018), Character 269.

1. Anterodorsal process of opercular (submarginal) ossification attaching onto skull: (0) absent; (1) present.

Zhu et al. (2016), Character 357; Zhu et al. (2021), Character 319)

1. Subopercular ossification: (0) absent; (1) present.

Coates et al. (2018), Character 58.

1. Lateral gular plates: (0) absent; (1) present.

Choo et al. (2017), Character 34; King et al. (2017), Character 167; Castiello (2018), Character 165.

1. Size of lateral gular plates: (0) extending most of length of the lower jaw; (1) restricted to the anterior third of the jaw (no longer than the width of three or four branchiostegals.

Choo et al. (2017), Character 35; King et al. (2017), Character 168; Castiello (2018), Character 166.

1. Median gular: (0) present; (1) absent.

Choo et al. (2017), Character 135; King et al. (2017), Character 169; Castiello (2018), Character 167.

*Dentition, dermal jaw & tooth-bearing bones*

1. Oral dermal tubercles borne on jaw cartilages: (0) absent; (1) present.

Choo et al. (2017), Character 38; King et al. (2017), Character 327; Castiello (2018), Character 319.

1. Oral dermal tubercles patterned in organised rows (teeth): (0) absent; (1) present.

Zhu et al. (2021), Character 76.

1. Teeth ankylosed to dermal bones: (0) absent; (1) present.

Choo et al. (2017), Character 42; King et al. (2017), Character 331; Castiello (2018), Character 323.

1. Dermal jaw plates on biting surface of jaw cartilages: (0) absent; (1) present.

Choo et al. (2017), Character 43; King et al. (2017), Character 332; Castiello (2018), Character 324.

1. Large dermal plates forming outer dental arcade: (0) only with denticles; (1) with large monolinear tooth row.

Choo et al. (2017), Character 202; King et al. (2017), Character 202; Castiello (2018), Character 201.

1. Dermal plates on mesial (lingual) surfaces of Meckel’s cartilage and palatoquadrate: (0) absent; (1) present.

Choo et al. (2017), Character 215; King et al. (2017), Character 358; Castiello (2018), Character 350.

1. Gnathal plates mesial to and/or above (or below) jaw cartilage: (0) absent; (1) present.

Coates et al. (2018), Character 90.

1. Deep, high supragnathal bone with durophagous occlusal surface: (0) absent; (1) present.

Long et al. (2015), Character 257; Choo et al. (2017), Character 249; Castiello (2018), Character 354. King et al. (2017), Character 364.

1. Posterior supragnathal with vertical pipe-like ridges: (0) absent; (1) present

King et al. (2017), Character 373; Castiello (2018), Character 362.

1. Strongly curved infragnathals with wide flat non-biting region: (0) absent; (1) present

King et al. (2017), Character 374; Castiello (2018), Character 363.

1. Number of fang pairs on ectopterygoid: (0) none; (1) one; (2) two.

King et al. (2017), Character 376; Castiello (2018), Character 365.

1. Enlarged anterior tooth on premaxilla: (0) absent; (1) present.

King et al. (2017), Character 379; Castiello (2018), Character 368.

1. Number of tooth rows on outer dental arcade: (0) single row; (1) two rows, with large teeth lingually and small teeth labially.

Lu et al. (2012), Character 123; King et al. (2017), Character 380; Castiello (2018), Character 369.

1. Number of infradentaries: (0) one; (1) two; (2) more than 2.

King et al. (2017), Character 381; Castiello (2018), Character 370.

1. Number of fang pairs on posterior coronoid: (0) none; (1) one; (2) two.

King et al. (2017), Character 383; Castiello (2018), Character 372.

1. Teeth radial rows on prearticular: (0) absent; (1) present.

King et al. (2017), Character 384; Castiello (2018), Character 373.

1. ’Symplectic’ articulation: (0) absent; (1) present.

King et al. (2017), Character 388; Castiello (2018), Character 376.

1. Processus ascendens of palatoquadrate: (0) absent; (1) present.

King et al. (2017), Character 389; Castiello (2018), Character 377.

1. Grooved, curved upper toothplates attached to median labial element: (0) absent; (1) present.

King et al. (2017), Character 390; Castiello (2018), Character 378.

1. Two divergent processes extending from anterior of palatoquadrate: (0) absent; (1) present.

King et al. (2017), Character 391; Castiello (2018), Character 379.

1. Extramandibular dentition: (0) absent; (1) present.

King et al. (2017), Character 392; Castiello (2018), Character 380.

1. Bilateral series of labial cartilages: (0) absent; (1) present.

King et al. (2017), Character 393; Castiello (2018), Character 381.

1. Maxilla and premaxilla sensu lato (upper gnathal plates lateral to jaw cartilage): (0) absent; (1) present.

Coates et al. (2018), Character 92.

1. Maxilla and premaxilla sensu stricto (upper gnathal plates lateral to jaw cartilage without palatal lamina): (0) absent; (1) present.

Coates et al. (2018), Character 93.

1. Tooth-bearing median rostral: (0) absent; (1) present.

Choo et al. (2017), Character 203; King et al. (2017), Character 346; Castiello (2018), Character 337.

1. Premaxillae with inturned symphysial processes: (0) absent; (1) present.

Choo et al. (2017), Character 184; King et al. (2017), Character 199; Castiello (2018), Character 198.

1. Premaxilla forming part of orbit: (0) absent; (1) present.

Choo et al. (2017), Character 185; King et al. (2017), Character 200; Castiello (2018), Character 199.

1. Premaxilla: (0) extends under orbit; (1) restricted anterior to orbit.

Choo et al. (2017), Character 286; King et al. (2017), Character 217; Castiello (2018), Character 216.

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

Choo et al. (2017), Character 186.

1. Ventral margin of maxilla: (0) straight; (1) curved.

Choo et al. (2017), Character 187; King et al. (2017), Character 201; Castiello (2018), Character 200.

1. Posterior expansion of maxilla (maxilla cleaver-shaped): (0) present; (1) absent.

Choo et al. (2017), Character 145; King et al. (2017), Character 175; Castiello (2018), Character 172.

1. Contribution by maxilla to posterior margin of cheek: (0) present; (1) absent.

Choo et al. (2017), Character 146; King et al. (2017), Character 176; Castiello (2018), Character 173.

1. Dentary marginal bone of mouth: (0) absent; (1) present.

Coates et al. (2018), Character 91. Zhu et al. (2021), Character 354.

1. Teeth of dentary: (0) reaching anterior end of dentary; (1) not reaching anterior end.

Choo et al. (2017), Character 204.

1. Pair of tooth plates (anterior supragnathals or vomers) on ethmoidal plate: (0) absent; (1) present.

Choo et al. (2017), Character 287; King et al. (2017), Character 367; Castiello (2018), Character 357

1. Fused anterior supragnathals: (0) absent; (1) present

Castiello (2018), Character 361; King et al. (2017), Character 372; Castiello (2018), Character 361.

1. Vomerine fangs: (0) absent; (1) present.

Choo et al. (2017), Character 225; King et al. (2017), Character 360; Castiello (2018), Character 352.

1. Vomeral area with grooves and raised areas: (0) absent; (1) present.

Choo et al. (2017), Character 226; King et al. (2017), Character 71; Castiello (2018), Character 73.

1. Posterior process of vomers: (0) absent; (1) present.

King et al. (2017), Character 375; Castiello (2018), Character 364.

1. Median dermal bone of palate (parasphenoid): (0) absent; (1) present.

Choo et al. (2017), Character 54; King et al. (2017), Character 131; Castiello (2018), Character 130.

1. Buccohypophysial canal in parasphenoid: (0) single; (1) paired.

Choo et al. (2017), Character 292; King et al. (2017), Character 74; Castiello (2018), Character 76.

1. Ascending process of parasphenoid: (0) absent; (1) present.

Choo et al. (2017), Character 154; King et al. (2017), Character 132; Castiello (2018), Character 131.

1. Shape of parasphenoid denticulated field: (0) broad rhomboid or lozenge-shaped; (1) broad, splint-shaped; (2) slender, splint-shaped.

Choo et al. (2017), Character 155; King et al. (2017), Character 133; Castiello (2018), Character 132.

1. Parasphenoid denticulated field with multifid anterior margin: (0) absent; (1) present.

Choo et al. (2017), Character 156; King et al. (2017), Character 134; Castiello (2018), Character 133.

1. Parasphenoid: (0) protruding forward into ethmoid region of endocranium; (1) behind ethmoid region.

Choo et al. (2017), Character 227; King et al. (2017), Character 135; Castiello (2018), Character 134.

1. Posterior of parasphenoid: (0) restricted to ethmosphenoid region; (1) extends to otic region.

Zhu et al. (2021), Character 261.

1. Denticulated field of parasphenoid: (0) without spiracular groove; (1) with spiracular groove.

Choo et al. (2017), Character 228; King et al. (2017), Character 136; Castiello (2018), Character 135.

1. Parasphenoid denticle field with anteriorly divergent lateral margins: (0) absent; (1) present.

Choo et al. (2017), Character 229.

1. Parasphenoid denticle field: (0) terminates at or anterior to level of foramina for internal carotid arteries; (1) extends posterior to foramina for internal carotid arteries.

Choo et al. (2017), Character 230; King et al. (2017), Character 137; Castiello (2018), Character 136.

1. Anterior portion of parasphenoid (pre-buccohypophyseal foramen) of greater length than posterior portion (post-foramen): (0) absent; (1) present.

Coates et al. (2018), Character 99.

1. Coronoids: (0) present, (1) absent.

King et al. (2017), Character 382; Castiello (2018), Character 371.

1. Number of coronoids: (0) more than three; (1) three.

Choo et al. (2017), Character 147; King et al. (2017), Character 344; Castiello (2018), Character 336.

1. Fangs of coronoids (sensu stricto): (0) absent; (1) present.

Choo et al. (2017), Character 148; King et al. (2017), Character 345; Castiello (2018), Character 337.

1. Dentition on coronoids: (0) broad marginal ‘tooth ﬁeld’; (1) narrow or single marginal tooth row.

Zhu et al. (2001), Zhu and Yu (2002), Character 70; Friedman (2007), Character 58; Zhu et al., 2009, Character 95; King et al. (2017), Character 348; Castiello (2018), Character 340.

1. Posterior coronoid: (0) similar to anterior coronoids; (1) forms expanded coronoid process.

Zhu et al. (2021), Character 247)

1. Infradentary: (0) absent; (1) present.

Choo et al. (2017), Character 206; King et al. (2017), Character 349; Castiello (2018), Character 341.

1. Extent of infradentaries: (0) along much of ventral margin of dentary; (1) restricted to posterior half of dentary.

Choo et al. (2017), Character 288; King et al. (2017), Character 368; Castiello (2018), Character 358.

1. Infradentary foramen and groove: (0) present; (1) absent.

Choo et al. (2017), Character 207; Coates et al. (2018), Character 95; King et al. (2017), Character 350; Castiello (2018), Character 342.

1. Large ventromesially directed flange of symphysial region of mandible: (0) absent; (1) present.

Choo et al. (2017), Character 208; King et al. (2017), Character 351; Castiello (2018), Character 343.

1. Extensive flange composed of prearticular and Meckelian bone that extends beyond ventral edge of outer dermal series: (0) absent; (1) present.

Choo et al. (2017), Character 330; King et al. (2017), Character 352; Castiello (2018), Character 344.

1. Strong ascending flexion of symphysial region of mandible: (0) absent; (1) present.

Choo et al. (2017), Character 210; King et al. (2017), Character 353; Castiello (2018), Character 345.

1. Parasymphysial plate: (0) detachable tooth whorl; (1) long with posterior corner, sutured to coronoid, denticulated or with tooth row; (2) absent.

Choo et al. (2017), Character 211; King et al. (2017), Character 354; Castiello (2018), Character 346.

1. Anterior end of prearticular: (0) far from jaw symphysis; (1) near jaw symphysis.

Choo et al. (2017), Character 212; King et al. (2017), Character 355; Castiello (2018), Character 347.

1. Prearticular - dentary contact: (0) present; (1) absent.

Choo et al. (2017), Character 213; King et al. (2017), Character 356; Castiello (2018), Character 348.

1. Number of dermopalatines: (0) one; (1) two; (2) more than 2

Castiello (2018), Character 367. King et al. (2017), Character 378. Zhu et al. (2021), Character 252.

1. Entopterygoids: (0) separated; (1) contact along midline.

Zhu et al. (2021), Character 253.

1. Proportions of entopterygoid: (0) anterior end level with processus ascendens; (1) anterior end considerably anterior to processus ascendens.

Castiello (2018), Character 366.

1. Course of mandibular canal: (0) passing through dentary; (1) not passing through dentary.

Choo et al. (2017), Character 218; Coates et al. (2018), Character 94; King et al. (2017), Character 299; Castiello (2018), Character 290.

1. Pharyngeal teeth or denticles: (0) absent; (1) present.

Coates et al. (2018), Character 78.

1. Lingual torus: (0) absent; (1) present.

Coates et al. (2018), Character 81.

1. Basolabial shelf: (0) absent; (1) present.

Coates et al. (2018), Character 82.

1. Tooth whorls: (0) absent; (1) present.

Choo et al. (2017), Character 39; King et al. (2017), Character 328; Castiello (2018), Character 320.

1. Distribution of tooth whorls: (0) upper and lower jaws; (1) lower jaws only; (2) upper jaws only.

Choo et al. (2017), Character 285; King et al. (2017), Character 366; Castiello (2018), Character 356

1. Bases of tooth whorls: (0) single, continuous plate; (1) some or all whorls consist of separate tooth units.

Choo et al. (2017), Character 40; King et al. (2017), Character 329; Castiello (2018), Character 321.

1. Enlarged adsymphysial tooth whorl: (0) absent; (1) present.

Choo et al. (2017), Character 41; King et al. (2017), Character 330; Castiello (2018), Character 322.

1. Tooth families/whorls: (0) restricted to symphysial region; (1) distributed along jaw margin. Coates et al. (2018), Character 83.
2. Number of tooth families/whorls per jaw ramus: (0) 15 or fewer; (1) 20 or more.

Coates et al. (2018), Character 84.

1. Tooth families/whorls: (0) continuous; (1) discontinuous.
2. Toothplates consolidated into one to three large posterior plates, and one to three smaller anterior tooth plates, occupying each quadrant of the jaw: (0) absent; (1) present.

Coates et al. (2018), Character 86.

Score changed from 0 (Coates et al., 2018) to - for *Austroptyctodus*, *Campbellodus* and *Rhamphodopsis*.

1. Toothplate complement restricted to two pairs in the upper jaw and a single pair in the lower jaw: (0) absent; (1) present.

Coates et al. (2018), Character 87.

Score changed from 0 (Coates et al., 2018) to - for *Austroptyctodus*, *Campbellodus* and *Rhamphodopsis*.

1. Length of dentary: (0) constitutes a majority of jaw length; (1) half the length of jaw or less.

Zhu et al. (2021), Character 242.

1. Labial pit: (0) absent; (1) present.

Zhu et al. (2021), Character 243; King et al. (2017), Character 385; Castiello (2018), Character 374.

1. Prearticular symphysis: (0) absent; (1) present.

Zhu et al. (2021), Character 244.

1. Retroarticular process: (0) absent; (1) present.

Zhu et al. (2021), Character 248; King et al. (2017), Character 386; Castiello (2018), Character 375.

*Mandibular arch*

1. Mandibular arch: (0) absent; (1) present.

Choo et al. (2017), Character 246.

1. Position of mandibular arch articulations: (0) terminal; (1) subterminal.

Zhu et al. (2021), Character 93)

1. Palatoquadrate relationship to dermal cheek bones: (0) articulation narrow and restricted; (1) broad articulation.

Zhu et al. (2021), Character 97.

1. Articulation between neurocranium and palatoquadrate posterodorsal to orbit (suprapterygoid articulation): (0) absent; (1) present.

Zhu et al. (2021), Character 144.

1. Articulation surface of the palatoquadrate with the postorbital (suprapteryoid) process: (0) directed anteriorly; (1) laterally; (2) dorsally.

Coates et al. (2018), Character 107.

1. Large otic process of the palatoquadrate: (0) absent; (1) present.

Choo et al. (2017), Character 45; King et al. (2017), Character 334; Castiello (2018), Character 326.

1. Laterally extending palatoquadrate: (0) absent; (1) present.

Zhu et al. (2016), Character 327; Zhu et al. (2021), Character 308.

1. Insertion area for jaw adductor muscles on palatoquadrate: (0) ventral; (1) lateral.

Choo et al. (2017), Character 46; King et al. (2017), Character 335; Castiello (2018), Character 327.

1. Oblique ridge or groove along medial face of palatoquadrate: (0) absent; (1) present.

Choo et al. (2017), Character 47; King et al. (2017), Character 336; Castiello (2018), Character 328.

1. Fenestration of palatoquadrate at basipterygoid articulation: (0) absent; (1) present.

Choo et al. (2017), Character 48; King et al. (2017), Character 337; Castiello (2018), Character 329.

1. Perforate or fenestrate anterodorsal (metapterygoid) portion of palatoquadrate: (0) absent; (1) present.

Choo et al. (2017), Character 49; King et al. (2017), Character 338; Castiello (2018), Character 330.

1. Metapterygoid with developed medial ventral protrusion: (0) absent; (1) present.

Choo et al. (2017), Character 244; King et al. (2017), Character 362; Castiello (2018), Character 353.

1. Autopalatine and quadrate: (0) comineralized; (1) separate mineralizations.

Choo et al. (2017), Character 290; King et al. (2017), Character 370; Castiello (2018), Character 359.

1. Palatoquadrate fused with neurocranium: (0) absent; (1) present.

Choo et al. (2017), Character 291; King et al. (2017), Character 371; Castiello (2018), Character 360.

1. Contact between palatoquadrate and dermal cheek bones: (0) continuous contact of metapterygoid and autopalatine; (1) metapterygoid and autopalatine contacts separated by gap between commissural lamina of palatoquadrate and cheek bones.

Choo et al. (2017), Character 243.

1. Position of upper mandibular arch cartilage (and associated cheek plate where present): (0) entirely suborbital; (1) with a postorbital extension.

Choo et al. (2017), Character 289.

1. Scalloped oral margin on Meckel’s cartilage and palatoquadrate: (0) absent; (1) present.

Coates et al. (2018), Character 113.

1. Mandibular symphysis fused: (0) absent; (1) present.

Coates et al. (2018), Character 114.

1. Pronounced dorsal process on Meckelian bone or cartilage: (0) absent; (1) present.

Choo et al. (2017), Character 50; King et al. (2017), Character 339; Castiello (2018), Character 331.

1. Meckelian bone exposed immediately anterior to first coronoid: (0) yes; (1) no.

Choo et al. (2017), Character 214; King et al. (2017), Character 357; Castiello (2018), Character 349.

1. Preglenoid process: (0) absent; (1) present.

Choo et al. (2017), Character 51; King et al. (2017), Character 340; Castiello (2018), Character 332.

1. Biconcave glenoid on lower jaw: (0) absent; (1) present.

Choo et al. (2017), Character 216; King et al. (2017), Character 359; Castiello (2018), Character 351.

1. Jaw articulation located on rearmost extremity of mandible: (0) absent; (1) present.

Choo et al. (2017), Character 52; King et al. (2017), Character 341; Castiello (2018), Character 333.

*Hyoid and gill arches*

1. Foramen in hyomandibular: (0) absent; (1) present.

Choo et al. (2017), Character 201; King et al. (2017), Character 142; Castiello (2018), Character 141.

1. Interhyal: (0) absent; (1) present.

Choo et al. (2017), Character 37; King et al. (2017), Character 141; Castiello (2018), Character 140.

1. Hypohyal: (0) absent; (1) present.

Choo et al. (2017), Character 282; King et al. (2017), Character 144; Castiello (2018), Character 143.

1. Disposition of the interbranchial ridges of the oralobranchial chamber roof: (0) oligobranchiate; (1) orthobranchiate; (2) nectaspidoform.

King et al. (2017), Character 146; Castiello (2018), Character 145.

1. Number of branchial fossae: (0) 5-7; (1) 9-17; (2) more than 20.

King et al. (2017), Character 147; Castiello (2018), Character 146.

1. Basibranchial elements: (0) unpaired; (1) paired.

King et al. (2017), Character 148; Castiello (2018), Character 147.

1. Sublingual rod: (0) absent; (1) present.

King et al. (2017), Character 149; Castiello (2018), Character 148.

1. Dense array of hyoid arch rays covers gill area: (0) absent; (1) present

King et al. (2017), Character 150; Castiello (2018), Character 149.

1. Endoskeletal urohyal: (0) absent; (1) present.

Choo et al. (2017), Character 283; King et al. (2017), Character 145; Castiello (2018), Character 144.

1. Urohyal shape (vertical plate): (0) absent; (1) present.

Choo et al. (2017), Character 329.

1. Basihyal: (0) absent; (1) present.

Choo et al. (2017), Character 36; King et al. (2017), Character 140; Castiello (2018), Character 139.

1. Ceratohyal smooth with posterior, lateral fossa: (0) absent; (1) present.

Coates et al. (2018), Character 69.

1. Anterior most unpaired element of branchial skeleton contacted by: (0) present; (1) absent.

Choo et al. (2017), Character 36. Coates et al. (2018), Character 71; Dearden et al. (2019), Character 73.

1. Multiple unpaired branchial mineralisations: (0) absent; (1) present.

Dearden et al. (2019), Character 74.

1. Posterior two ventral branchial arches:0 separate; (1) articulate ventrally.

Dearden et al. (2019), Character 80.

1. Posterior two dorsal branchial arches: (0) separate; (1) articulate dorsally.

Dearden et al. (2019), Character 81.

1. Gill arches: (0) largely restricted to region under braincase; (1) extend far posterior to braincase.

Choo et al. (2017), Character 281; King et al. (2017), Character 143; Castiello (2018), Character 142.

1. Gill skeleton extends posteriorly beyond occiput: (0) absent; (1) present.

Coates et al. (2018), Character 66. Dearden et al. (2019), Character 67.

1. First branchial arch meets neurocranium: (0) ventral to otic region; (1) posterior to otic region.

Dearden et al. (2019), Character 68; Zhu et al. (2021), Character 355.

1. Separate supra- and infra-pharyngobranchials: (0) absent; (1) present.

Coates et al. (2018), Character 72.

1. Pharyngobranchial orientation: (0) directed anteriorly; (1) posteriorly.

Coates et al. (2018), Character 73.

1. Posteriormost branchial arch bears epibranchial unit: (0) absent; (1) present.

Coates et al. (2018), Character 74.

1. Epibranchials bear posterior flange: (0) absent; (1) present.

Coates et al. (2018), Character 75.

1. Hypobranchial orientation: (0) directed anteriorly; (1) hypobranchials of second and more posterior gill arches directed posteriorly.

Coates et al. (2018), Character 76.

*Neurocranium*

1. Endoskeletal intracranial joint: (0) absent; (1) present.

Choo et al. (2017), Character 60; King et al. (2017), Character 25; Castiello (2018), Character 25.

1. Discrete division of the ethmoid and more posterior braincase at the level of the optic tract canal (optic fissue): (0) absent; (1) present.

Choo et al. (2017), Character 247; Zhu et al. (2021), Character 118; King et al. (2017), Character 73; Castiello (2018), Character 75.

1. Ventral cranial fissure: (0) absent; (1) present.

Choo et al. (2017), Character 92. King et al. (2017), Character 54; Castiello (2018), Character 55.

1. Metotic (otic-occipital) fissure: (0) absent; (1) present.

Choo et al. (2017), Character 93. King et al. (2017), Character 55; Castiello (2018), Character 56.

1. External nasal opening: (0) single median; (1) paired.

Castiello (2018), Character 226.

1. Nasal opening(s): (0) dorsal, placed between orbits; (1) ventral and anterior to orbits.

Choo et al. (2017), Character 55. King et al. (2017), Character 20; Castiello (2018), Character 20.

1. Nasohypophyseal opening shape: (0) unconstructed; (1) constriction between nasal and hypophysial divisions; (2) split into nasal and hypophysial divisions.

Castiello (2018), Character 227.

1. Endoskeletal lamina (postnasal wall) separating posterior nostril and orbit: (0) absent; (1) present.

Clement et al. (2018), Character 281.

1. Orbitonasal lamina dorsoventrally deep: (0) absent; (1) present.

Coates et al. (2018), Character 122.

1. Size of profundus canal in postnasal wall: (0) small; (1) large.

Choo et al. (2017), Character 333.

1. Three large pores (in addition to nostrils) associated with each side of ethmoid: (0) absent; (1) present.

Zhu et al. (2021), Character 257.

1. Ventral face of nasal capsule in taxa with mineralized ethmoid: (0) complete; (1) fenestra ventrolateralis; (2) entire floor unmineralized.

Choo et al. (2017), Character 172; Zhu et al. (2021), Character 258.

1. Fenestra ventrolateralis: (0) absent; (1) present; (2) common ventral fenestra for anterior and posterior nostrils.

Choo et al. (2017), Character 219.

1. Precerebral fontanelle: (0) absent; (1) present.

Choo et al. (2017), Character 53. King et al. (2017), Character 19; Castiello (2018), Character 19.

1. Olfactory tracts: (0) short, with olfactory capsules situated close to telencephalon cavity; (1) elongate and tubular (much longer than wide).

Choo et al. (2017), Character 56. King et al. (2017), Character 21; Castiello (2018), Character 21.

1. Olfactory tracts: (0) parallel or near-parallel; (1) significantly diverged.

Zhu et al. (2021), Character 342.

1. Prominent pre-orbital rostral expansion of the neurocranium: (0) present; (1) absent.

Choo et al. (2017), Character 57.

The coding of *Ramirosuarezia* is changed from 0 to 1.

1. Ethmoid region elongate with dorsoventrally deep lateral walls: (0) absent; (1) present.

Choo et al. (2017), Character 72. King et al. (2017), Character 36; Castiello (2018), Character 36.

1. Ethmoid articulation for palatoquadrate: (0) placed on postnasal wall; (1) extends posteriorly to the level of N.II.

Choo et al. (2017), Character 242; King et al. (2017), Character 72; Castiello (2018), Character 74.

1. Internasal vacuities or pits: (0) absent; (1) present.

Lu et al. (2016), Character 49; Coates et al. (2018), Character 116.

1. Morphology of internasal vacuities: (0) undifferentiated or anterior palatal fossa; (1) shallow, paired pits with strong midline ridge; (2) deep, peer-shaped pits.

Lu et al. (2016), Character 49; Choo et al. (2017), Character 245.

1. Basicranial morphology: (0) platybasic; (1) tropibasic.

Choo et al. (2017), Character 73.

1. Narrow interorbital septum: (0) absent; (1) present.

Choo et al. (2017), Character 67. King et al. (2017), Character 32; Castiello (2018), Character 32.

1. Optic lobes: (0) narrower than cerebellum; (1) same width or wider than cerebellum.

Lu et al. (2017), Character 271.

1. Space for forebrain and (at least) proximal portion of olfactory tracts narrow and elongate, extending between orbits: (0) absent; (1) present.

Coates et al. (2018), Character 118. Zhu et al. (2021), Character 347.

1. Rostral bar: (0) absent; (1) present.

Coates et al. (2018), Character 120.

1. Anteriormost articulation for the mandibular arch: (0) located anterior to the nasal capsules, terminal; (1) immediately below or posterior to nasal capsules, subterminal.

Zhu et al. (2016), Character 326; Coates et al. (2018), Character 123; Zhu et al. (2021), Character 307.

1. Palatobasal (or orbital) articulation: (0) posterior to the optic foramen; (1) anterior to the optic foramen, grooved, and overlapped by process or flange of palatoquadrate; (2) anterior to optic foramen, smooth, and overlaps or flanks articular surface on palatoquadrate.

Coates et al. (2018), Character 124.

1. Close association of pineal organ and nasal cavities: (0) absent; (1) present.

Zhu et al. (2016), Character 328; Zhu et al. (2021), Character 309.

1. Trochlear nerve foramen anterior to optic nerve foramen: (0) absent; (1) present.

Coates et al. (2018), Character 126; Zhu et al. (2021), Character 349.

1. Pronounced sub-ethmoidal keel: (0) absent; (1) present.

Choo et al. (2017), Character 58; King et al. (2017), Character 23; Castiello (2018), Character 23.

1. Eyestalk or unfinished area on neurocranial wall for eyestalk: (0) absent; (1) present.

Choo et al. (2017), Character 149; King et al. (2017), Character 62; Castiello (2018), Character 63.

1. Eye stalk position: (0) positioned laterally on the orbital wall; (1) positioned ventrally on the subocular shelf wall.

Castiello (2018), Character 64.

1. Position of myodome for superior oblique eye muscles: (0) posterior and dorsal to foramen for nerve II; (1) anterior and dorsal to foramen.

Choo et al. (2017), Character 59; King et al. (2017), Character 24; Castiello (2018), Character 24.

1. Orbit directed mostly laterally and free of flanking endocranial cartilage or bone: (0) absent; (1) present.

Coates et al. (2018), Character 128.

1. Orbit dorsal or facing dorsolaterally, surrounded laterally by endocranium: (0) present; (1) absent.

Choo et al. (2017), Character 65.

1. Orbit larger than otic capsule: (0) absent; (1) present.

Coates et al. (2018), Character 142.

1. Paired pineal and parapineal tracts: (0) absent; (1) present.

Choo et al. (2017), Character 334.

1. Endoskeletal spiracular canal: (0) open; (1) partial enclosure or spiracular bar; 2 complete enclosure in canal.

Choo et al. (2017), Character 335.

1. Developed postorbital cavity: (0) absent; (1) present.

Choo et al. (2017), Character 220.

1. Unconstricted cranial notochord: (0) absent; (1) present.

Choo et al. (2017), Character 221; King et al. (2017), Character 68; Castiello (2018), Character 70.

1. Descending process of sphenoid (with its posterior extremity lacking periostegeal lining): (0) absent; (1) present.

Choo et al. (2017), Character 222; King et al. (2017), Character 69; Castiello (2018), Character 71.

1. Opercular suspension on braincase: (0) absent; (1) present.

Choo et al. (2017), Character 224; King et al. (2017), Character 70; Castiello (2018), Character 72.

1. Ophthalmic foramen in anterodorsal extremity of orbit communicates with cranial interior: (0) absent; (1) present.

Coates et al. (2018), Character 132.

1. Internal carotids: (0) entering single or paired openings in the basicranium from a posterolateral angle; (1) entering basicranial opening(s) head-on from an extreme, lateral angle; (2) absent.

Coates et al. (2018), Character 137.

Internal carotids converging almost head-on toward the midline (Schaeffer, 1981; Maisey, 1983) is shared by *Synechodus* and Recent elasmobranchs (Maisey, 1985).

1. Entrance of internal carotids: (0) through separate openings flanking the hypophyseal opening or recess; (1) through a common opening at the central midline of the basicranium.

Choo et al. (2017), Character 78; King et al. (2017), Character 41; Castiello (2018), Character 41.

1. Postorbital process: (0) absent; (1) present.

Choo et al. (2017), Character 295; Coates et al. (2018), Character 165; King et al. (2017), Character 77; Castiello (2018), Character 79; Zhu et al. (2021), Character 346.

1. Elongated distance between postorbital process and the articulation for hyomandibular: (0) absent; (1) present.
2. Postorbital process articulates with palatoquadrate: (0) absent; (1) present.

Choo et al. (2017), Character 80; King et al. (2017), Character 43; Castiello (2018), Character 43.

1. Postorbital process and arcade: (0) short and deep - width not more than maximum braincase width (excluding arcade); (1) process and arcade wide - width exceeds maximum width of braincase, and anteroposteriorly narrow; (2) process and arcade massive; (3) arcade forms postorbital pillar.

Coates et al. (2018), Character 144; Zhu et al. (2021), Character 345.

1. Postorbital process downturned, with anhedral angle relative to basicranium: (0) absent; (1) present.

Coates et al. (2018), Character 145.

1. Canal for jugular in postorbital process: (0) absent; (1) present.

Choo et al. (2017), Character 296; King et al. (2017), Character 78; Castiello (2018), Character 80.

1. Jugular canal diameter: (0) small; (1) large; (2) canal absent.

Coates et al. (2018), Character 146.

1. Jugular canal: (0) long (invested in otic region along length of skeletal labyrinth); (1) short (restricted to region anterior of skeletal labyrinth); (2) absent (jugular vein uninvested in otic region).

Choo et al. (2017), Character 294; King et al. (2017), Character 76; Castiello (2018), Character 78.

1. Canal, likely for trigeminal nerve (V) mandibular ramus, passes through the postorbital process from proximal dorsal entry to distal and ventral exit: (0) absent; (1) present.

Coates et al. (2018), Character 147.

1. Postorbital process expanded anteroposteriorly: (0) absent; (1) present.

Coates et al. (2018), Character 148.

1. C-bout notch separates postorbital process from supraotic shelf: (0) absent; (1) present.

Coates et al. (2018), Character 152.

1. Series of perforations for innervation of supraorbital sensory canal in supraorbital shelf: (0) absent; (1) present.

Choo et al. (2017), Character 297; King et al. (2017), Character 79; Castiello (2018), Character 81.

1. Spiracular groove on basicranial surface: (0) absent; (1) present.

Choo et al. (2017), Character 61; King et al. (2017), Character 26; Castiello (2018), Character 26.

1. Spiracular groove on lateral commissure: (0) absent; (1) present.

Choo et al. (2017), Character 62; King et al. (2017), Character 27; Castiello (2018), Character 27.

1. Subpituitary fenestra: (0) absent; (1) present.

Choo et al. (2017), Character 63; King et al. (2017), Character 28; Castiello (2018), Character 94.

1. Supraorbital shelf broad with convex lateral margin: (0) absent; (1) present.

Choo et al. (2017), Character 64; King et al. (2017), Character 29; Castiello (2018), Character 28.

1. Nerve VIII bifurcates before entering the labyrinth cavity: (0) bifurcates; (1) does not bifurcate.

Zhu et al. (2021), Character 341.

1. Prehypophysial diencephalon: (0) the prehypophysial ventral “step” is absent or insignificantly captured by endocast, the ventral aspect of telencephalon is continuous with the anterior boundary of the hypophysial recess; (1) significant prehypophysial diencephalon, indicated by a “step” between the optic nerve canal marking the start of the diencephalon, and the anterior boundary of the hypophysial recess.

Zhu et al. (2021), Character 343.

1. Otic or pre-vagus section of myelencephalon: (0) long, longer than metencephalon; (1) short, shorter than metencephalon.

Zhu et al. (2021), Character 344.

1. Extended prehypophysial portion of sphenoid: (0) absent; (1) present.

Choo et al. (2017), Character 66. King et al. (2017), Character 31; Castiello (2018), Character 31.

1. Main trunk of facial nerve: (0) elongate and passes anterolaterally through orbital floor; (1) stout and divides within otic capsule at the level of the postorbital process.

Choo et al. (2017), Character 68.

1. Hyoid ramus of facial nerve exits through posterior jugular opening: (0) absent; (1) present.

Choo et al. (2017), Character 69; King et al. (2017), Character 33; Castiello (2018), Character 33.

1. Ascending basisphenoid pillar pierced by common internal carotid: (0) absent; (1) present.

Choo et al. (2017), Character 74; King et al. (2017), Character 38; Castiello (2018), Character 38.

1. Canal for efferent pseudobranchial artery within basicranial cartilage: (0) absent; (1) present.

Choo et al. (2017), Character 75; King et al. (2017), Character 39; Castiello (2018), Character 39.

1. Position of basal/basipterygoid articulation: (0) same anteroposterior level as hypophysial opening; (1) anterior to hypophysial opening.

Choo et al. (2017), Character 79; King et al. (2017), Character 42; Castiello (2018), Character 42.

1. Basipterygoid process (basal articulation) with vertically oriented component: (0) absent; (1) present.

Choo et al. (2017), Character 82; King et al. (2017), Character 45; Castiello (2018), Character 45.

1. Expanded articular area anterior to basipterygoid process: (0) absent; (1) present.

King et al. (2017), Character 103; Castiello (2018), Character 104.

1. Pituitary vein canal: (0) dorsal to level of basipterygoid process; (1) flanked posteriorly by basipterygoid process.

Choo et al. (2017), Character 83; King et al. (2017), Character 46; Castiello (2018), Character 46.

1. Pituitary vein canal: (0) discontinuous, enters the cranial cavity; (1) discontinuous, enters hypophysial recess; (2) continuous transverse vein.

Clement et al. (2018), Character 282.

1. Pituitary vein in a transverse canal connecting the orbit: (0) absent; (1) present.

Castiello (2018), Character 93.

1. Short otico-occipital region of braincase: (0) absent; (1) present.

Choo et al. (2017), Character 71; King et al. (2017), Character 35; Castiello (2018), Character 35.

1. Position of hyomandibula articulation on neurocranium: (0) absent; (1) present.

Choo et al. (2017), Character 76.

1. Articulation facet with hyomandibular: (0) single-headed; (1) double-headed.

Choo et al. (2017), Character 150; King et al. (2017), Character 63; Castiello (2018), Character 65.

1. Position of hyomandibula articulation on neurocranium: (0) below or anterior to orbit, on ventrolateral angle of braincase; (1) on otic capsule, posterior to orbit.

Zhu et al. (2021), Character 157.

1. Position of hyomandibula articulation relative to structure of skeletal labyrinth: (0) anterior or lateral to skeletal labyrinth; (1) at level of posterior semicircular canal.

Zhu et al. (2021), Character 158.

1. Hyomandibula articulates with neurocranium beneath otic shelf: (0) absent; (1) present.

Coates et al. (2018), Character 162.

1. Hyoid arch articulation: (0) on lateral commissure; (1) on otic capsule wall.

Choo et al. (2017), Character 223.

1. Relative position of jugular groove and hyomandibular articulation: (0) hyomandibula dorsal or same level (i.e. on bridge); (1) jugular vein passing dorsal or lateral to hyomandibula.

Choo et al. (2017), Character 324.

1. Hyomandibular facets where they straddle the jugular vein: (0) narrowly separated; (1) widely separated.

King et al. (2017), Character 104; Castiello (2018), Character 105.

1. Hypophyseal chamber: (0) projects posteroventrally; (1) projects ventrally or anteroventrally.

Zhu et al. (2021), Character 266.

1. Cuccullaris fossa (trapezius fossa): (0) open posteriorly; (1) constrained posteriorly.

Zhu et al. (2016), Character 324; Zhu et al. (2021), Character 306.

1. Cranial cavity and labyrinth: (0) widely spaced; (1) closely spaced.

Lu et al. (2017), Character 273.

1. Labyrinth cavity: (0) separated from the main neurocranial cavity by a cartilaginous or ossified capsular wall; (1) skeletal capsular wall absent.

Choo et al. (2017), Character 81; King et al. (2017), Character 44; Castiello (2018), Character 44.

1. External (horizontal) semicircular canal: (0) absent; (1) present.

Choo et al. (2017), Character 84; King et al. (2017), Character 47; Castiello (2018), Character 47.

1. External (horizontal) semicircular canal: (0) joins the vestibular region dorsal to posterior ampulla; (1) joins level with posterior ampulla.

Choo et al. (2017), Character 86; King et al. (2017), Character 49; Castiello (2018), Character 49.

1. Horizontal semicircular canal in dorsal view: (0) medial to path of jugular vein; (1) dorsal to jugular vein.

Choo et al. (2017), Character 299; King et al. (2017), Character 81; Castiello (2018), Character 83.

1. Crus commune connecting anterior and posterior semicircular canals: (0) present; (1) absent.

Coates et al. (2018), Character 180; Zhu et al. (2021), Character 279)

1. Crus commune of anterior and posterior semicircular canals: (0) dorsal to endocranial roof; (1) ventral to endocranial roof.

Lu et al. (2017), Character 272.

1. Angle of external semicircular canal: in lateral view, straight line projected through canal intersects anterior ampulla, external ampullae, and base of foramen magnum: (0) absent; (1) present.

Coates et al. (2017; Character 101); Coates et al. (2018), Character 177; Zhu et al. (2021), Character 350.

1. Left and right external semicircular canals approach or meet the posterodorsal midine of the hindbrain roof: (0) absent; (1) present.

Coates et al. (2018), Character 178; Zhu et al. (2021), Character 351.

1. Preampullary portion of posterior semicircular canal: (0) absent; (1) present.

Maisey (2001), Character 17; Coates et al. (2018), Character 179; Zhu et al. (2021), Character 332.

1. Sinus superior: (0) absent or indistinguishable from union of anterior and posterior canals with saccular chamber; (1) present.

Choo et al. (2017), Character 85; King et al. (2017), Character 41; Castiello (2018), Character 41; Zhu et al. (2021), Character 331.

1. Supraotic cavity: (0) absent; (1) present.

Lu et al. (2017), Character 275.

1. Lateral cranial canal: (0) absent; (1) present.

Choo et al. (2017), Character 152; King et al. (2017), Character 64; Castiello (2018), Character 66.

1. Subcircular endolymphatic foramen: (0) absent; (1) present.

Coates et al. (2018), Character 185.

1. External opening for endolymphatic ducts anterior to crus commune: (0) absent; (1) present.

Coates et al. (2018), Character 186; Zhu et al. (2021), Character 352.

1. Endolymphatic ducts: (0) posteriodorsally angled tubes; (1) tubes oriented vertically through median endolymphatic fossa.

Choo et al. (2017), Character 91.

1. Ampullary ends of anterior semicircular canal and external semicircular canal: (0) separated by the bulbous utricular chamber; (1) join before entering utricular chamber.

Maisey (2001), Character 25; Zhu et al. (2021), Character 333.

1. Orientation of saccular cavity in anterior view: (0) flat inclined; (1) steeply inclined or vertical.

Zhu et al. (2021), Character 334.

1. Sacculus position: (0) restricted ventral to external semicircular canal; (1) extends dorsal to semicircular canal.

Zhu et al. (2021), Character 335.

1. Vestibular cavity of the bony labyrinth shape: (0) drum-shaped; (1) irregularly shaped.

Zhu et al. (2021), Character 336.

1. Endolymphatic complex shape: (0) simple and tube-like; (1) differentiated into distinctive sections.

Zhu et al. (2021), Character 337.

1. Endolymphatic complex position: (0) lateral to the otic cartilaginous wall, close to inner ear; (1) mesial to the cartilaginous wall, close to brain cavity.

Zhu et al. (2021), Character 338.

1. Endolymphatic duct distal direction in lateral view: (0) posteriorly directed; (1) vertically directed.

Zhu et al. (2021), Character 339.

1. Endolymphatic duct distal direction in coronal view: (0) parallelled directed; (1) mesially directed; (2) laterally directed.

Zhu et al. (2021), Character 340.

1. Endolymphatic fossa: (0) absent; (1) present.

Coates et al. (2018), Character 190.

1. Endolymphatic sacs: (0) absent; (1) present; (2) medially oriented endolymphatic fossae; (3) laterally oriented endolymphatic fossae.

Castiello (2018), Character 54

1. Endolymphatic fossa elongate (slot-shaped), dividing dorsal otic ridge along midline: (0) absent; (1) present.

Coates et al. (2018), Character 191.

1. Perilymphatic fenestra within the endolymphatic fossa: (0) absent; (1) present.

Coates et al. (2018), Character 192; King et al. (2017), Character 119; Castiello (2018), Character 121; Zhu et al. (2021), Character 353.

1. Trigemino-facial recess: (0) absent; (1) present.

Choo et al. (2017), Character 87.

1. Posterior dorsal fontanelle: (0) absent; (1) present.

Choo et al. (2017), Character 88; King et al. (2017), Character 50; Castiello (2018), Character 50.

1. Shape of posterior dorsal fontanelle: (0) approximately as long as broad; (1) much longer than wide, slot-shaped.

Choo et al. (2017), Character 89. King et al. (2017), Character 51; Castiello (2018), Character 51.

1. Posterior dorsal fontanelle: (0) connected to persistent otico-occipital fissure; (1) separated from the fissure by posterior tectum.

Coates et al. (2018), Character 184.

1. Course of hyoid ramus of facial nerve (N. VII) relative to jugular canal: (0) traverses jugular canal, with separate exit in otic region; (1) intersects jugular canal, with exit through posterior jugular foramen.

Zhu et al. (2021), Character 135.

1. Relationship of cranial endocavity to basisphenoid: (0) endocavity occupies full depth of sphenoid; (1) enodcavity dorsally restricted.

King et al. (2017), Character 37; Castiello (2018), Character 37; Zhu et al. (2021), Character 137.

1. Supraotic shelf broad: (0) absent; (1) present.

Coates et al. (2018), Character 187.

1. Dorsal otic ridge: (0) absent; (1) present.

Choo et al. (2017), Character 90; King et al. (2017), Character 52; Castiello (2018), Character 52;

Zhu et al. (2021), Character 155.

1. Dorsal otic ridge forms a crest posteriorly: (0) absent; (1) present.

Coates et al. (2018), Character 189; King et al. (2017), Character 118; Castiello (2018), Character 120.

1. Vestibular fontanelle: (0) absent; (1) present.

Choo et al. (2017), Character 94; King et al. (2017), Character 56; Castiello (2018), Character 57.

1. Hypotic lamina (and dorsally directed glossopharyngeal canal): (0) absent; (1) present.

Choo et al. (2017), Character 99; King et al. (2017), Character 61; Castiello (2018), Character 62.

1. Basicranial fenestra: (0) absent; (1) present.

Choo et al. (2017), Character 151; King et al. (2017), Character 64; Castiello (2018), Character 66.

1. Channel for dorsal aorta and/or lateral dorsal aortae: (0) passes through basicranium: 1 external to basicranium.

Coates et al. (2018), Character 201; Choo et al. (2017), Character 77; King et al. (2017), Character 40; Castiello (2018), Character 40.

*Ellopetalichthys* is coded as “0” (Castiello et al., 2020).

1. Dorsal aorta divides into lateral dorsal aortae: (0) posterior to occipital level; (1) anterior to level of the occiput.

Coates et al. (2018), Character 202; Choo et al. (2017), Character 153; King et al. (2017), Character 66; Castiello (2018), Character 68.

1. Transverse otic process: (0) present; (1) absent.

Choo et al. (2017), Character 293; King et al. (2017), Character 75; Castiello (2018), Character 77.

1. Subcranial ridges: (0) absent; (1) present.

Choo et al. (2017), Character 298; King et al. (2017), Character 80; Castiello (2018), Character 82.

1. Synotic tectum: (0) absent; (1) present.

Choo et al. (2017), Character 300; King et al. (2017), Character 82; Castiello (2018), Character 84.

1. Shape of median dorsal ridge anterior to endolymphatic fossa: (0) developed as a squared-off ridge or otherwise ungrooved; (1) bears a midline groove.

Choo et al. (2017), Character 301; King et al. (2017), Character 83; Castiello (2018), Character 85.

1. Medial recess of the posteroventral mydome: (0) absent; (1) present.

King et al. (2017), Character 89; Castiello (2018), Character 91.

1. Abducens, trigeminal nerves and pituitary vein: (0) opening via different foramina on the orbital wall; (1) sharing the same foramen on the orbital wall.

Castiello (2018), Character 92.

1. Number of "sel" canals: (0) five; (1) less than 5.

King et al. (2017), Character 91; Castiello (2018), Character 95.

1. ’sel’ 1 canal bifurcation: (0) between orbit and field; (1) adjacent to lateral field; (2) adjacent to orbit.

King et al. (2017), Character 92; Castiello (2018), Character 96.

1. Marginal vein: (0) absent; (1) present.

King et al. (2017), Character 92; Castiello (2018), Character 97.

1. Profundus nerve (Young 1980): (0) emerges from the cranial cavity separately from the trigeminal nerve; (1) emerges together with the trigeminal nerve.

King et al. (2017), Character 94; Castiello (2018), Character 98.

1. Transverse otic process: (0) not extending in front of orbits; (1) extending in front of orbits.

King et al. (2017), Character 95; Castiello (2018), Character 99.

1. Nasal capsules in anterolateral corners of orbit: (0) no; (1) yes.

King et al. (2017), Character 96; Castiello (2018), Character 100.

1. Vagal process: (0) forked; (1) unforked.

King et al. (2017), Character 97; Castiello (2018), Character 101.

1. Rostral processes: (0) absent; (1) present.

King et al. (2017), Character 99; Castiello (2018), Character 102.

1. Median rostral dorsal process of the braincase: (0) absent; (1) present.

King et al. (2017), Character 100; Castiello (2018), Character 103.

1. Posttemporal fossae: (0) absent; (1) present.

King et al. (2017), Character 106; Castiello (2018), Character 106.

1. Rostral organ: (0) absent; (1) present

King et al. (2017), Character 107; Castiello (2018), Character 107.

1. Prespiracular dental plate: (0) absent; (1) present.

King et al. (2017), Character 108; Castiello (2018), Character 108.

1. Suprapterygoid process: (0) absent; (1) present.

King et al. (2017), Character 109; Castiello (2018), Character 109.

1. Processus supraorbitalis lateralis: (0) absent; (1) present.

King et al. (2017), Character 110; Castiello (2018), Character 110.

1. Anterolateral fenestra in roof of otoccipital: (0) absent; (1) present.

King et al. (2017), Character 111; Castiello (2018), Character 111.

1. Ventral cranial fissure connects with vestibular fontanelles: (0) absent; (1) present.

King et al. (2017), Character 112; Castiello (2018), Character 112.

1. Bar across spiracular groove: (0) absent; (1) present.

King et al. (2017), Character 113; Castiello (2018), Character 113.

1. Hypophysial opening in braincase: (0) absent; (1) present.

King et al. (2017), Character 114; Castiello (2018), Character 114.

1. Hypophysial organ projection: (0) anterior (1) anteroventral (2) posteroventral

Castiello (2018), Character 115.

1. Ventral rounded processes on preotic part of braincase: (0) absent; (1) present

King et al. (2017), Character 116; Castiello (2018), Character 118.

1. Notochord short, ending at the occipital cotylus: (0) absent; (1) present

King et al. (2017), Character 120; Castiello (2018), Character 122.

1. Accessory processes extend from ventral surface of nasal capsule: (0) absent; (1) present

King et al. (2017), Character 124; Castiello (2018), Character 123.

1. Internal carotid meets efferent pseudobranchial in orbit: (0) absent; (1) present

King et al. (2017), Character 125; Castiello (2018), Character 124.

1. Jugular vein passes through cranioquadrate passage: (0) absent; (1) present.

King et al. (2017), Character 126; Castiello (2018), Character 125.

1. Anterior margin of ventral fissure: (0) straight; (1) sinusoidal.

King et al. (2017), Character 126; Castiello (2018), Character 126.

1. Bulbous otic and auxiliary condyles for palatoquadrate articulation: (0) absent; (1) present.

King et al. (2017), Character 128; Castiello (2018), Character 127.

1. Basal fenestra opening into floor of orbit: (0) absent; (1) present.

King et al. (2017), Character 129; Castiello (2018), Character 128.

1. Nasal sacs: (0) unpaired; (1) paired.

King et al. (2017), Character 130; Castiello (2018), Character 129.

1. 4 carotid foramina in parasphenoid: (0) absent; (1) present.

King et al. (2017), Character 138; Castiello (2018), Character 137.

1. Parotic dental plates: (0) absent; (1) present.

King et al. (2017), Character 139; Castiello (2018), Character 138.

1. Branchial ridges: (0) present; (1) reduced to vagal process; 2 absent (articulation made with bare cranial wall).

Choo et al. (2017), Character 302; King et al. (2017), Character 84; Castiello (2018), Character 86.

1. Periotic process: (0) absent; (1) present.

Coates et al. (2018), Character 156; King et al. (2017), Character 117; Castiello (2018), Character 119.

1. Sub-otic occipital fossa: (0) absent; (1) present.

Coates et al. (2018), Character 163.

1. Postotic process: (0) absent; (1) present.

Coates et al. (2018), Character 165.

1. Otic capsule extends posterolaterally relative to occipital arch: (0) absent; (1) present.

Coates et al. (2018), Character 166.

1. Otic capsules: (0) widely separated; (1) approaching dorsal midline.

Coates et al. (2018), Character 167.

1. Otic capsules project anteriorly between postorbital processes: (0) absent; (1) present.

Coates et al. (2018), Character 168.

1. Endocranial roof anterior to otic capsules domelike, smoothly convex dorsally and anteriorly: (0) absent; (1) present.

Coates et al. (2018), Character 169.

1. Roof of skeletal cavity for cerebellum and mesencephalon significantly higher than dorsal-most level of semicircular canals: (0) absent; (1) present.

Coates et al. (2018), Character 170.

1. Roof of the endocranial space for telencephalon and olfactory tracts offset ventrally relative to level of mesencephalon: (0) absent; (1) present.

Coates et al. (2018), Character 171. Zhu et al. (2021), Character 348;

1. Double octaval nerve foramina in chondrified mesial wall of otic capsule: (0) absent; (1) present.

Coates et al. (2018), Character 173.

1. Glossopharyngeal nerve exit: (0) foramen situated posteroventral to otic capsule and anterior to metotic fissure; (1) through metotic fissure.

Choo et al. (2017), Character 70. King et al. (2017), Character 34; Castiello (2018), Character 34.

1. Glossopharyngeal and vagus nerves share common exit from neurocranium: (0) absent; (1) present.

Coates et al. (2018), Character 199.

1. Ventral portion of occipital arch wedged between rear of otic capsules: (0) absent; (1) present.

Coates et al. (2018), Character 203; King et al. (2017), Character 57; Castiello (2018), Character 58.

1. Dorsal portion of occipital arch wedged between otic capsules: (0) absent; (1) present.

Choo et al. (2017), Character 95; Coates et al. (2018), Character 204; King et al. (2017), Character 57; Castiello (2018), Character 58.

1. Craniospinal process ("supravagal process" in Stensio): (0) absent; (1) present.

Choo et al. (2017), Character 303; King et al. (2017), Character 85; Castiello (2018), Character 87.

1. Parachordal shape: (0) forming a broad, flat surface as wide as the otic capsules; (1) mediolaterally constricted relative to the otic capsules.

Choo et al. (2017), Character 98; King et al. (2017), Character 60; Castiello (2018), Character 61.

1. Ventral notch between parachordals: (0) absent; (1) present or entirely unfused.

Choo et al. (2017), Character 97; King et al. (2017), Character 59; Castiello (2018), Character 60.

1. Stalk-shaped parachordal/occipital region: (0) absent; (1) present.

Choo et al. (2017), Character 304; King et al. (2017), Character 86; Castiello (2018), Character 88.

1. Size of aperture to notochordal canal: (0) much smaller than foramen magnum; (1) as large, or larger, than foramen magnum.

Choo et al. (2017), Character 306; King et al. (2017), Character 88; Castiello (2018), Character 90.

1. Spino-occipital nerve foramina: (0) two or more, aligned horizontally; (1) one or two, dorsoventrally offset.

Choo et al. (2017), Character 96.

1. Occipital crest anteroposteriorly elongate, and extends from the roof of the posterior tectum: (0) absent; (1) present.

Coates et al. (2018), Character 205.

1. Paired occipital condyles: (0) absent; (1) present.

Choo et al. (2017), Character 305; Coates et al. (2018), Character 206; King et al. (2017), Character 87; Castiello (2018), Character 89.

*Axial and appendicular skeleton*

1. Macromeric dermal shoulder girdle: (0) present; (1) absent.

Choo et al. (2017), Character 100; King et al. (2017), Character 421; Castiello (2018), Character 410.

1. Dermal neck-joint between paired main-lateral-line-bearing bones of skull and shoulder girdle: (0) absent; (1) present.

Choo et al. (2017), Character 177; King et al. (2017), Character 192; Castiello (2018), Character 191.

1. Dorsal articular lamina on trunk armour: (0) absent; (1) present.

Zhu et al. (2019), Character 3; Zhu et al. (2021), Character 356.

1. Cranial fossa receiving the ventral articular lamina of the trunk: (0) absent; (1) present.

Zhu et al. (2019), Character 4; Zhu et al. (2021), Character 357.

1. Trunk ventral articular lamina develops into flange or condyle: (0) absent, continuous along the articular lamina of the anterior dorsolateral plate; (1) present, the articular lamina develops into distinctive flange or condyle.

Zhu et al. (2019), Character 5; Zhu et al. (2021), Character 358.

1. Rotatory contact of the articulation: (0) absent; (1) present

Zhu et al. (2019), Character 8; Zhu et al. (2021), Character 359.

1. Lateral ridges on skull roof laterally defines the articulation: (0) absent; (1) present.

Zhu et al. (2019), Character 8; Zhu et al. (2021), Character 360.

1. Dermal shoulder girdle composition: (0) ventral and dorsal (scapular) components; (1) ventral components only.

Choo et al. (2017), Character 101; King et al. (2017), Character 422; Castiello (2018), Character 411.

1. Dermal shoulder girdle forming a complete ring around the trunk: (0) present; (1) absent.

Choo et al. (2017), Character 102; King et al. (2017), Character 423; Castiello (2018), Character 412.

1. Pectoral fenestra completely encircled by dermal shoulder armour: (0) present; (1) absent.

Choo et al. (2017), Character 103; King et al. (2017), Character 424; Castiello (2018), Character 413.

1. Median dorsal plate: (0) absent; (1) present.

Choo et al. (2017), Character 104; King et al. (2017), Character 425; Castiello (2018), Character 414.

1. Pronounced internal crista (keel) on median dorsal surface of shoulder girdle: (0) absent; (1) present.

Choo et al. (2017), Character 105; King et al. (2017), Character 426; Castiello (2018), Character 415.

1. Anterior median dorsal plate: (0) absent; (1) present.

Zhu et al. (2016), Character 358; Zhu et al. (2021), Character 320.

1. Anterior margin of unpaired anterior median dorsal plate: (0) broad; (1) pointed.

Zhu et al. (2016), Character 362; Zhu et al. (2021), Character 322.

1. Anterior median dorsal plate (MD1) relative to posterior median dorsal plate (MD2) in length: (0) MD1 shorter than MD2; (1) MD1 longer than MD2.

Zhu et al. (2016), Character 36; Zhu et al. (2021), Character 321.

1. Anterior lateral plate: (0) absent; (1) present.

Zhu et al. (2016), Character 363; Zhu et al. (2021), Character 323.

1. Postbranchial lamina of trunk armour: (0) lateral; (1) internal.

Zhu et al. (2016), Character 364; Zhu et al. (2021), Character 324.

1. Crista internalis of dermal shoulder girdle: (0) absent; (1) present.

Zhu et al. (2021), Character 183.

1. Anteroventral plate: (0) absent; (1) present.

Zhu et al. (2016), Character 365; Zhu et al. (2021), Character 325.

1. Number of median ventral plates: (0) two; (1) one.

Zhu et al. (2016), Character 366; Zhu et al. (2021), Character 326.

1. Interolateral plate: (0) paired; (1) fused (unpaired semilunar plate).

Zhu et al. (2016), Character 367; Zhu et al. (2021), Character 327.

1. Anterior ventrolateral plates of both sides: (0) in contact; (1) separated.

Zhu et al. (2016), Character 368; Zhu et al. (2021), Character 328.

1. Brachial process: (0) absent; (1) present.

Zhu et al. (2016), Character 369; Zhu et al. (2021), Character 329.

1. Presupracleithrum: (0) absent; (1) present.

Choo et al. (2017), Character 231; King et al. (2017), Character 203; Castiello (2018), Character 202.

1. Anocleithrum: (0) element developed as postcleithrum; (1) element developed as anocleithrum sensu stricto.

Choo et al. (2017), Character 232; King et al. (2017), Character 430; Castiello (2018), Character 419.

1. Dorsal cleithrum (AL of the Placodermi), ventral cleithrum (AVL of the Placodermi) and pectoral spine (SP of the Placodermi): (0) not fused; (1) fused.

Choo et al. (2017), Character 234; King et al. (2017), Character 431; Castiello (2018), Character 420.

1. Shape of dorsal blade of dermal shoulder girdle: (0) spatulate; (1) pointed.

Choo et al. (2017), Character 307; King et al. (2017), Character 435; Castiello (2018), Character 424.

1. Posterior dorsolateral plate or equivalent: (0) absent; (1) present.

Choo et al. (2017), Character 308; King et al. (2017), Character 436; Castiello (2018), Character 425.

1. Relationship of clavicle to cleithrum: (0) ascending process of clavicle overlapping cleithrum laterally; (1) ascending process of clavicle wrapping round anterior edge of cleithrum, overlapping it both laterally and mesially.

Choo et al. (2017), Character 235; King et al. (2017), Character 432; Castiello (2018), Character 421.

1. Paired fins relation to cephalic shield: (0) continuous;(1) delimited at pectoral sinus.

Castiello (2018), Character 383.

1. Intromittent organ for internal fertilization (’claspers’): (0) absent; (1) present.

King et al. (2017), Character 395; Castiello (2018), Character 385.

1. Entepicondyle on humerus: (0) present; (1) absent.

King et al. (2017), Character 418; Castiello (2018), Character 407.

1. PL and PDL overlap: (0) simple; (1) insertion.

King et al. (2017), Character 437; Castiello (2018), Character 426.

1. Left and right posterior dorsolateral plates contact below the median dorsal plate: (0) absent; (1) present.

King et al. (2017), Character 438; Castiello (2018), Character 427.

1. PDL plate visible externally: (0) present; (1) absent.

King et al. (2017), Character 439; Castiello (2018), Character 428.

The original character state formulation was incorrect by comparison to their codings in the data set.

1. Posteriorly produced spine on MD plate: (0) absent; (1) present.

King et al. (2017), Character 440; Castiello (2018), Character 429.

1. Joint in macromeric armoured pectoral fin: (0) absent; (1) present.

King et al. (2017), Character 441; Castiello (2018), Character 430.

1. Cd1 (first dorsal central) and Cd2 (second dorsal central) plates: (0) in contact; (1) separated.

King et al. (2017), Character 442; Castiello (2018), Character 431.

1. Clavicles/interolateral plates: (0) large plates, comparable in size to cleithrum; (1) paired small semilunar plates; (2) unpaired semilunar plates.

King et al. (2017), Character 443; Castiello (2018), Character 432.

1. Chang’s apparatus: (0) absent; (1) present.

King et al. (2017), Character 444; Castiello (2018), Character 433.

1. Number of median dorsal plates: (0) one; (1) two; (2) three.

King et al. (2017), Character 445; Castiello (2018), Character 434.

1. Anocleithrum sensu stricto: (0) exposed; (1) subdermal.

King et al. (2017), Character 446; Castiello (2018), Character 435.

1. Median ventral trunk plates: (0) absent; (1) present.

King et al. (2017), Character 447; Castiello (2018), Character 436.

1. Extracleithrum: (0) absent; (1) present.

King et al. (2017), Character 448; Castiello (2018), Character 437.

1. Pectoral fin spine small (bivalve-like): (0) absent; (1) present.

Castiello (2018), Character 438. King et al. (2017), Character 449.

1. Dorsal branch of main lateral line canal on posterior dorsolateral plate: (0) present; (1) absent.

King et al. (2017), Character 325; Castiello (2018), Character 317.

The original character state formulation was incorrect by comparison to their codings in the data set.

1. Sharp downward bend in posterior dorsolateral plate sensory line: (0) absent; (1) present.

King et al. (2017), Character 326; Castiello (2018), Character 318.

1. Horizontal caudal lobe: (0) absent; (1) present.

King et al. (2017), Character 451; Castiello (2018), Character 440.

1. Triphycercal tail: (0) absent; (1) present.

King et al. (2017), Character 4521; Castiello (2018), Character 441.

1. Spine-brush complex: (0) absent; (1) present.

King et al. (2017), Character 479; Castiello (2018), Character 468.

1. Series of median hexagonal scutes anterior to first dorsal fin: (0) absent; (1) present.

King et al. (2017), Character 480; Castiello (2018), Character 469.

1. Intermediate spines with finlets: (0) absent; (1) present.

King et al. (2017), Character 481; Castiello (2018), Character 470.

1. Median ventral prepectoral spine: (0) absent; (1) present.

King et al. (2017), Character 482; Castiello (2018), Character 471.

1. Prepectoral spines form "necklace": (0) absent; (1) present.

King et al. (2017), Character 483; Castiello (2018), Character 472.

1. Longitudinal rows of enlarged keeled scutes: (0) absent; (1) present.

King et al. (2017), Character 484; Castiello (2018), Character 473.

1. Endoskeletal supports in pectoral fin: (0) multiple elements articulating with girdle; (1) single element ("humerus") articulating with girdle.

Choo et al. (2017), Character 233; King et al. (2017), Character 409; Castiello (2018), Character 398.

1. Triradiate scapulocoracoid: (0) absent; (1) present.

Choo et al. (2017), Character 236; King et al. (2017), Character 410; Castiello (2018), Character 399.

1. Flange on trailing edge of scapulocoracoid: (0) absent; (1) present.

Choo et al. (2017), Character 109; King et al. (2017), Character 401; Castiello (2018), Character 390.

1. Horizontal plate of scapulocoracoid: (0) absent; (1) present.

King et al. (2017), Character 419; Castiello (2018), Character 408.

1. Subscapular foramen: (0) absent; (1) present.

Choo et al. (2017), Character 237; King et al. (2017), Character 411; Castiello (2018), Character 400.

1. Scapular process of shoulder endoskeleton: (0) absent; (1) present.

Choo et al. (2017), Character 106; King et al. (2017), Character 398; Castiello (2018), Character 387.

1. Scapular process with posterodorsal angle: (0) absent; (1) present.

Choo et al. (2017), Character 110; King et al. (2017), Character 402; Castiello (2018), Character 391.

1. Scapular infundibulum: (0) absent; (1) present.

Choo et al. (2017), Character 309; King et al. (2017), Character 413; Castiello (2018), Character 402.

1. Ventral margin of separate scapular ossification: (0) horizontal; (1) deeply angled.

Choo et al. (2017), Character 107; King et al. (2017), Character 399; Castiello (2018), Character 388.

1. Cross sectional shape of scapular process: (0) flattened or strongly ovate; (1) subcircular.

Choo et al. (2017), Character 108; King et al. (2017), Character 400; Castiello (2018), Character 389.

1. Endoskeletal postbranchial lamina on scapular process: (0) present; (1) absent.

Choo et al. (2017), Character 111; King et al. (2017), Character 403; Castiello (2018), Character 392.

1. Mineralisation of internal surface of scapular blade: (0) mineralised all around; (1) unmineralised on internal face forming a hemicylindrical cross-section.

Choo et al. (2017), Character 112; King et al. (2017), Character 404; Castiello (2018), Character 393.

1. Coracoid process: (0) absent; (1) present.

Choo et al. (2017), Character 113; King et al. (2017), Character 405; Castiello (2018), Character 394.

1. Procoracoid mineralisation: (0) absent; (1) present.

Choo et al. (2017), Character 114; King et al. (2017), Character 406; Castiello (2018), Character 395.

1. Paired (pectoral) fins: (0) absent; (1) present.

Castiello (2018), Character 382.

1. Pectoral fins covered in macromeric dermal armour: (0) absent; (1) present.

Choo et al. (2017), Character 120.

1. Armoured pectoral appendage: (0) unjointed; (1) jointed.

Zhu et al. (2016), Character 371; Zhu et al. (2021), Character 330.

1. Pectoral fin base has large, hemispherical dermal component: (0) absent; (1) present.

Choo et al. (2017), Character 121; King et al. (2017), Character 427; Castiello (2018), Character 416.

1. Pectoral fin articulation: (0) monobasal; (1) dibasal; 2 three or more basals.

Choo et al. (2017), Character 310; Coates et al. (2018), Character 227; King et al. (2017), Character 414; Castiello (2018), Character 403.

1. Fin base articulation on scapulocoracoid: (0) deeper than wide (stenobasal); (1) wider than deep (eurybasal).

Choo et al. (2017), Character 115; King et al. (2017), Character 407; Castiello (2018), Character 396.

1. Number of mesomeres in metapterygial axis: (0) five or fewer; (1) seven or more.

Choo et al. (2017), Character 311; King et al. (2017), Character 415; Castiello (2018), Character 404.

1. Biserial pectoral fin endoskeleton: (0) absent; (1) present.

Choo et al. (2017), Character 312; King et al. (2017), Character 416; Castiello (2018), Character 405.

1. Filamentous extension of pectoral fin from axillary region: (0) absent; (1) present.

Choo et al. (2017), Character 313; King et al. (2017), Character 417; Castiello (2018), Character 406.

1. Metapterygium pectinate subtriangular plate or bar supporting numerous (six or more) radials along distal edge: (0) absent; (1) present.

Coates et al. (2018), Character 228.

1. Metapterygial whip: (0) absent; (1) present.

Coates et al. (2018), Character 229.

1. Pectoral propterygium: (0) absent; (1) present.

Choo et al. (2017), Character 238; King et al. (2017), Character 412; Castiello (2018), Character 401.

1. Perforate propterygium: (0) absent; (1) present.

Choo et al. (2017), Character 116; King et al. (2017), Character 408; Castiello (2018), Character 397.

1. Distal articulation of propterygium: (0) with fin rays; (1) with a second enlarged element; (2) no articulation.

King et al. (2017), Character 420; Castiello (2018), Character 409.

1. Pelvic fins: (0) absent; (1) present.

Choo et al. (2017), Character 117; King et al. (2017), Character 394; Castiello (2018), Character 384.

1. Pelvic girdle with substantial dermal component: (0) yes; (1) no.

Choo et al. (2017), Character 239; King et al. (2017), Character 433; Castiello (2018), Character 422.

1. Dermal pelvic clasper ossifications: (0) absent; (1) present.

Choo et al. (2017), Character 119; King et al. (2017), Character 396; Castiello (2018), Character 386.

1. Pelvic fin: (0) monobasal; (1) polybasal.

Lu et al. (2017), Character 278.

1. Intromittent organ containing bone, not associated with pelvic fins: (0) absent; (1) present.

Choo et al. (2017), Character 118.

1. Intromittent organ with one large J-shaped element: (0) absent; (1) present.

Choo et al. (2017), Character 250.

1. Intromittent organ ('clasper') consisting entirely of cartilage, formed from distal part of pelvic fin: (0) absent; (1) present.

Choo et al. (2017), Character 251.

1. Pelvic girdle with fused puboischiadic bar: (0) absent; (1) present.

Coates et al. (2018), Character 233.

1. Mixipterygial/mixopterygial claspers: (0) absent; (1) present.

Coates et al. (2018), Character 234.

1. Pre-pelvic clasper or tenaculum: (0) absent; (1) present.

Coates et al. (2018), Character 236.

1. Number of dorsal fins, if present: (0) one; (1) two.

Choo et al. (2017), Character 132; King et al. (2017), Character 450; Castiello (2018), Character 439.

1. Posterior dorsal fin shape: (0) base approximately as broad as tall, not broader than all of other median fins; (1) base much longer than the height of the fin, substantially longer than any of the other dorsal fins.

Choo et al. (2017), Character 320; King et al. (2017), Character 476; Castiello (2018), Character 465.

1. Basal plate in dorsal fin (Friedman & Brazeau (2010: character 42)): (0) absent; (1) present.

Choo et al. (2017), Character 321; King et al. (2017), Character 477; Castiello (2018), Character 466.

1. Branching radial structure articulating with dorsal fin basal plate: (0) absent; (1) present.

Choo et al. (2017), Character 322; King et al. (2017), Character 456; Castiello (2018), Character 445.

1. Branching radials in paired fins: (0) absent; (1) present.

Zhu et al. (2021), Character 197.

1. Posterior or pelvic-level dorsal fin with calcified base plate: (0) absent; (1) present.

Coates et al. (2018), Character 241.

1. Posterior dorsal fin with delta-shaped cartilage: (0) absent; (1) present.

Coates et al. (2018), Character 242.

1. Anal fin: (0) absent; (1) present.

Choo et al. (2017), Character 133; King et al. (2017), Character 466; Castiello (2018), Character 455.

1. Basal plate in anal fin (Friedman & Brazeau (2010: character 42)): (0) absent; (1) present.

Choo et al. (2017), Character 323; King et al. (2017), Character 478; Castiello (2018), Character 467.

1. Anal fin base narrow, posteriormost proximal segments radials broad: (0) absent; (1) present.

Coates et al. (2018), Character 245.

1. Caudal radials: (0) extend beyond level of body wall and deep into hypochordal lobe; (1) restricted to axial lobe.

Choo et al. (2017), Character 134; King et al. (2017), Character 453; Castiello (2018), Character 442.

1. Series of thoracic supraneurals: (0) absent; (1) present.

Choo et al. (2017), Character 319; King et al. (2017), Character 455; Castiello (2018), Character 444.

1. Supraneurals in axial lobe of caudal fin: (0) absent; (1) present.

Choo et al. (2017), Character 314; King et al. (2017), Character 454; Castiello (2018), Character 443.

1. Caudal neural and/or supraneural spines or radials: (0) short; (1) long, expanded, and supporting high aspect-ratio (lunate) tail with notochord extending to posterodorsal extremity; (2) notochord terminates pre-caudal extremity, neural and heamal radial lengths near symmetrical and support epichordal and hypochordal lobes respectively.

Coates et al. (2018), Character 247.

1. Synarcual: (0) absent; (1) present.

Choo et al. (2017), Character 131; King et al. (2017), Character 465; Castiello (2018), Character 454.

1. Calcified vertebral centra: (0) absent; (1) present.

Coates et al. (2018), Character 207.

1. Chordacentra: (0) absent; (1) present.

Coates et al. (2018), Character 208.

1. Chordacentra polyspondylous and consist of narrow closely packed rings: (0) absent; (1) present.

Coates et al. (2018), Character 209.

1. Brush complex of bilaterally distributed calcified tubes flanking or embedded in calcified cartilage core: (0) absent; (1) present.

Coates et al. (2018), Character 240.

*Spines: fins, cranial and elsewhere*

1. Dorsal fin spine: (0) absent; (1) present.

Choo et al. (2017), Character 122; King et al. (2017), Character 457; Castiello (2018), Character 446.

1. Dorsal fin spine at anterior (pectoral level) location only: (0) absent; (1) present.

Coates et al. (2018), Character 249.

1. Anal fin spine: (0) absent; (1) present.

Choo et al. (2017), Character 123; King et al. (2017), Character 458; Castiello (2018), Character 447.

1. Pectoral fin spine: (0) absent; (1) present.

Choo et al. (2017), Character 124; King et al. (2017), Character 429; Castiello (2018), Character 418.

1. Pelvic fin spine: (0) absent; (1) present.

Choo et al. (2017), Character 240; King et al. (2017), Character 434; Castiello (2018), Character 423.

1. Median fin spine insertion: (0) shallow, not greatly deeper than dermal bones / scales; (1) deep.

Choo et al. (2017), Character 125; King et al. (2017), Character 459; Castiello (2018), Character 448.

1. Intermediate fin spines: (0) absent; (1) present.

Choo et al. (2017), Character 126; King et al. (2017), Character 460; Castiello (2018), Character 449.

1. Intermediate spines when present: (0) one pair; (1) multiple pairs.

Choo et al. (2017), Character 316; King et al. (2017), Character 473; Castiello (2018), Character 462.

1. Prepectoral fin spines: (0) absent; (1) present.

Choo et al. (2017), Character 127; King et al. (2017), Character 461; Castiello (2018), Character 450.

1. Anteriormost intermediate spine associated with shoulder girdle: (0) absent; (1) present.

Coates et al. (2018), Character 256. Dearden et al. (2019), Character 261.

1. Cephalic spines: (0) absent; (1) present.

Choo et al. (2017), Character 268; Coates et al. (2018), Character 262 King et al. (2017), Character 206; Castiello (2018), Character 205.

1. Pectoral fin spine with denticles along posterior surface: (0) absent; (1) present.

Coates et al. (2018), Character 254.

1. Fin spines with ridges: (0) absent; (1) present.

Choo et al. (2017), Character 128; King et al. (2017), Character 462; Castiello (2018), Character 451.

1. Fin spines with nodes: (0) absent; (1) present.

Choo et al. (2017), Character 129; King et al. (2017), Character 463; Castiello (2018), Character 452.

1. Fin spines with rows of large retrorse denticles: (0) absent; (1) present.

Choo et al. (2017), Character 130; King et al. (2017), Character 464; Castiello (2018), Character 453.

1. Fin spines (dorsal) with rows of large denticles: (0) absent; (1) on posterior surface; (2) on lateral surface.

Coates et al. (2018), Character 261.

1. Fin spine cross-section: (0) round or horseshoe shaped; (1) flat-sided, with rectangular profile.

Choo et al. (2017), Character 315; King et al. (2017), Character 472; Castiello (2018), Character 461.

1. Expanded spine rib on leading edge of spine: (0) absent; (1) present.

Choo et al. (2017), Character 317; King et al. (2017), Character 474; Castiello (2018), Character 463.

1. Spine ridges: (0) converging at the distal apex of the spine; (1) converging on leading edge of spine.

Choo et al. (2017), Character 318; King et al. (2017), Character 475; Castiello (2018), Character 464.

1. Dorsal fin spine cross section: (0) horseshoe shaped; (1) flat sided, with rectangular profile; (2) subcircular.

Coates et al. (2018), Character 250.

1. Anterior dorsal fin spine leading edge concave in lateral view: (0) absent; (1) present.

Coates et al. (2018), Character 251.