Structural diversity in the cranial musculoskeletal system in Anguilliformes: an evolutionary-morphological study

Part 2 - Figures

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Heterenchelyidae

Pythonichthys macrurus

Anguillidae

Anguilla anguilla

Moringuidae

Moringua edwardsi

Ophichthidae

Pisodonophis boro

Other Anguilliformes
**Figure 4.1:** Cladogram of the taxa examined in this study (modified after Böhlke (1989a). Anguillidae and Moringuidae are monophyletic following Obermiller and Pfeiler (2003). **Features related to head-first burrowing:** Eye reduction (hf1), Widened cephalic lateral line system that extends into the dermal cavities (hf2), Ventral positioning of gill opening (hf3), Caudoventral orientation of the anterior section of the adductor mandibulae muscle complex (hf4), Skull with short and sharp snout (hf5), Large insertion sites of body muscles on the neurocranium (hf6); **Unique characters of** *Pythonichthys macrurus*: Frontal arches (u1), Preopercle with arch-like structures (u2), Tubular and arch-like circumorbital bones (u3), Arch-like suprapreopercular bone (u4), Two ring-like extrascapular bones (u5) and Caudal positioning of the levator arcus palatini muscle (u6), Merging left and right bundles of the sternohyoideus and protractor hyoidei muscles (u7); **Others:** Absence of basisphenoid (o1), Separate vomeronasal bone (o2), Premaxillo-ethmovomerine complex (o3), Connection of the palatopterygoid at its two ends (o4), Well-developed pectoral fins (o5), Absence of A1 section of the adductor mandibulae muscle complex (o6).
Figure 4.2. Neurocranial bones of *Pythonichthys macrurus*. (a) Dorsal view and (b) ventral view. af susp A, anterior suspensorial articulation facet; af susp p, posterior suspensorial articulation facet; fr-Tri.fac, foramen trigemino-facialis; Lat exp-F, lateral expansion of frontal bone; o-BOc, basioccipital bone; o-BSph, basisphenoid; o-Epi, epioccipital bone; o-ExOc, exoccipital bone; o-F, frontal bone; o-Par, parietal bone; o-PMx-Et, premaxillo-ethmoid complex; o-Pro, prootic bone; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid; o-SOc, supraoccipital bone; o-Sph, sphenotic bone; o-Vo, vomeral bone.
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Figure 4.5. Jaw of *Pythonichthys macrurus* (right side) (a-b) maxillary bone; lateral view (a), medial view (b) and (c) lower jaw (medial view). af Md, mandibular articulation facet; ac Mx-Et, maxillo-ethmoidal articulation condyle; ca-CorMec, coronomeckelian cartilage, L Iop-Ang, interoperculo-angular ligament; L Pop-Ang, preoperculo-angular ligament; o-Ang, angular bony complex; o-D, dentary; o-Mx, maxillary bone; fs Mec, meckelian fossa; pr Cor, coronoid process; pr ra, process of retroarticular bone.
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c POM, preopercular mandibular canal; l-IOp-Ang, interoperculo-angular ligament; m-A2α, ventral subsection of A2; m-A2β, dorsal subsection of A2; m-A3, A3 section of the adductor mandibulae muscle complex; m-AAP, adductor arcus palatini muscle; m-HH inf, hyohyoideus inferioris muscle; m-LAPa, anterior subsection of levator arcus palatini muscle; m-PH, protractor hyoidei muscle; m-SH, sternohyoideus muscle; m-SPH, pharyngocleithralis muscle; o-D, dentary complex; t A2β, tendon of A2β.
Figure 5.6: Opercular series and hyoid apparatus of *Simenchelys parasiticus*: (a) Opercular series; lateral view (right side), and (b) hyoid apparatus; ventral and dorsal views of the dorsal hypohyal, ventral hypohyal, anterior ceratohyal and posterior ceratohyal bones, ventral and dorsal views of urohyal, and dorsal view of basihyal. af Hhy, hypohyal articular facet; af Op, opercular articular facet; ac Hhy, hypohyal articular condyle; l-CH-Ang, ceratohyalo-angular ligament; o-BH, basihyal; o-CH A, anterior ceratohyal bone; o-CH p, posterior ceratohyal bone; o-Hhy D, dorsal hypohyal bone; o-Hhy V, ventral hypohyal bone; o-Iop, interopercle; o-Op, opercle; o-POp, preopercle; o-SOp, subopercle; o; o-UH, urohyal; pr UH, urohyal process; Pop W, preopercular wing.
Figure 5.7: Gill arches of *Simenchelys parasiticus*. (a) Dorsal view of the ventral part and the ventral view of the dorsal part of the gill arch, and (b) gill arch muscles. o-Bb, basibranchial bone; o-Cb, ceratobranchial bone; o-Eb, epibranchial bone; o-Hb, hypobranchial bone; o-Ib, infrapharyngobranchial bone; o-LP, lower pharyngeal tooth plates; o-UP, upper pharyngeal tooth plates; m-APTp, pharyngeal tooth plate adductor muscle; m-Le, levator externus muscle; m-Li, levator internus muscle; m-PHC, pharyngocleithralis muscle; m-SPH, subpharyngealis muscle; m-Trans.v, transversus ventralis muscle.
**Figure 5.8:** The cranial muscles of *Simenchelys parasiticus*. (a) Skin removed (lateral view), (b) sections A2 except for the medial fibers of subsection A2α, hyohyoideus muscle, hyohyoideus inferioris muscle, epaxial muscles, hypaxial muscles, ventral muscles of the head and primordial ligament are removed (lateral view), (c) subsection A2α, section A3, lateral fibers of the levator arcus palatini muscle and levator operculi muscle are removed (lateral view), and (d) ventral muscles of head (sagittal left cut), hyohyoideus muscle is removed. l-Iop-Ang, interoperculo-angular ligament; l-prim, primordial ligament; m-A2α, ventral subsection of A2; m-A2β, dorsal subsection of A2; m-A2αm, medial fibers of ventral subsection of A2; m-A3, A3 section of the adductor mandibulae muscle complex; m-AAP, adductor arcus palatini muscle; m-AO, adductor operculi muscle; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH inf, hyohyoideus inferioris muscle; m-HH sup, hyohyoideus superior muscle; m-LAPa, anterior subsection of levator arcus palatini muscle; m-LAPp, posterior subsection of levator arcus palatini muscle; m-LO, levator operculi muscle; m-PH, protractor hyoidei muscle; m-SH, sternohyoideus muscle; m-SPH, subpharyngealis muscle; m-Trans.v, transversus ventralis muscle; o-Cb, ceratobranchial bone; o-CH A, anterior ceratohyal bone; o-Cl, cleithrum bone; o-D, dentary complex; o-F, frontal bone; o-Hb, hypobranchial bone; o-Hhy V, ventral hypohyal bone; o-Mx, maxillary bone; o-Op, opercle; o-Par, parietal bone; o-PMx-Et, premaxillo-ethmoidal complex; o-POp, preopercle; o-PP, palatopterygoid bone; t-A2β, tendon of A2β; t-DO, tendon of dilatator operculi muscle; t-LAPa, tendon of anterior subsection of levator arcus palatini; t-LAPp, tendon of posterior subsection of levator arcus palatini; t-LO, tendon of levator operculi.
**Figure 5.9:** The cranial muscles of *Ilyophis brunneus*. (a) Skin removed (lateral view); (b) sections A2, hyohyoideus muscle, lateral fibers of the levator/adductor operculi muscle, epaxial muscles, hypaxial muscles, maxillary bone, branchiostegal rays and primordial ligament are removed (lateral view); (c) ventral view of the right side of the cranial muscles (Skin is removed and subpharyngealis muscle is cut). l-Iop-Ang, interoperculo-angular ligament; l-CH-Ang, cratohyal-angular ligament; l-prim, primordial ligament; l-Mx-PMx-Et, maxillo-premaxillo-ethmoidal ligament; l-UH-BH, urohyalo-basihyal ligament; m-A2a, ventral subsection of A2; m-A2β, dorsal subsection of A2; m-A3, A3 section of the adductor mandibulae muscle complex; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH, hyohyoideus muscle complex; m-LAP, levator arcus palatini muscle; m-L/AO1, lateral fibers of levator/adductor operculi muscle; m-L/AOm, medial fibers of levator/adductor operculi muscle; m-PH, protractor hyoidei muscle; m-SH, sternohyoideus muscle; m-SPH, subpharyngealis muscle; o-CH A, anterior ceratohyal bone; o-Cl, cleithrum bone; o-D, dentary complex; o-F, frontal bone; o-IOp, interopercle; o-Mx, maxillary bone; o-Op, opercle; o-POp, preopercle; o-SOp, subopercle; o-UH, urohyal bone; t-A2β, tendon of A2β; t.a-PH, anterior tendon of protractor hyoidei muscle; t.p-PH, posterior tendon of protractor hyoidei muscle; t-SH, tendon of sternohyoideus muscle.
**Figure 5.10:** The cranial muscles of *Synaphobranchus brevidorsalis.* (a) Skin removed (lateral view), (b) Sections A2, hyohyoideus muscle, levator operculi muscle, epaxial muscles, hypaxial muscles, maxillary bone and primordial ligament are removed (lateral view), and (c) ventral muscles of head; left lower jaw, anterior and posterior ceratohyal, and left muscle bundle of the protractor hyoidei (m-PH), and sternohyoideus (m-SH) are removed. l-Iop-Ang, interoperculo-angular ligament; l-prim, primordial ligament; l-Pg-Q, pterygoideo-quadrangle ligament; m-AAP, adductor arcus palatini; m-A2α, ventral subsection of A2; m-A2β, dorsal subsection of A2; m-A3, A3 section of the adductor mandibulae muscle complex; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH, hyohyoideus muscle complex; m-LAP, levator arcus palatini muscle; m-AO, adductor operculi muscle; m-LO, levator operculi muscle; m-PH.I, lateral fibers of protractor hyoidei muscle; m-PHC, pharyngocleithralis; m-SH, sternohyoideus muscle; o-BH, basihyal; o-CH A, anterior ceratohyal bone; o-Cl, cleithrum bone; o-D, dentary complex; o-F, frontal bone; o-Hhy, hypohyal bone; o-Iop, interopercle; o-Mx, maxillary bone; o-Op, opercle; o-PMx-Et, premaxillo-ethmoidal complex; o-Pg, pterygoid bone; o-SOp, subopercle; o-UH, urohyal bone; t-DO, tendon of dilatator operculi muscle; t-SH, tendon of sternohyoideus muscle.
Figure 6.1. Functional morphological model of pharyngeal jaw movement in M. retifera. The left dentary has been removed in a–c, and the left maxilla has been removed in b and c. a, Pharyngeal jaw apparatus at rest. b, Pharyngeal jaw protracted: the levator internus (LI) and levator externus (LE) protract the upper jaw into the oral cavity, whereas the rectus communis (RC) protracts the lower jaw. During protraction, the upper pharyngobranchial is dorsally rotated by contraction of the LI and the obliquus dorsalis (OD). c, After prey contact, the adductor (AD) contracts to bring the upper and lower jaws together to deliver a second bite. The dorsal retractor (DR) and pharyngocleitheralis (PHC) retract the pharyngeal jaws back to their resting position behind the skull. Scale bar, 1 cm (after Mehta and Wainwright, 2007a).
Figure 6.2: Neurocranium of *Ariosoma gilberti*. (a) Dorsal view and (b) ventral view. af susp A, anterior suspensorial articulation facet; af susp p, posterior suspensorial articulation facet; fr-Opt, foramen opticum; fr-Tri.fac, foramen trigemino-facialis; o-BOc, basioccipital bone; o-BSph, basisphenoid; o-Epi, epioccipital bone; o-ExOc, exoccipital bone; o-F, frontal bone; o-Par, parietal bone; o-PMx-Etv, premaxillo-ethmovomerual complex; o-Pro, prootic bone; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid; o-Sph, sphenotic bone.
Figure 6.3: Cranial skeleton of *Ariosoma gilberti* (Lateral view). (a) Complete skull (right side) and (b) suspensorium (right side). ac Op, opercular articular condyle; af susp p, posterior suspensorial articulation facet; ac susp A, anterior suspensorial condyle; ac susp P, posterior suspensorial condyle; o-Ang, angular bony complex; o-BSph, basisphenoid bone; o-D, dentary complex; o-Epi, epioccipital bone; o-ExOc, exoccipital bone; o-F, frontal bone; o-Hm, hyomandibular bone; o-Iop, interopercle; o-Mx, maxillary bone; o-Op, opercle; o-Par, parietal bone; o-PMx-Etv, premaxillo-ethmovomeral complex; o-POp, preopercle; o-PP, palatopterygoid; o-Pro, prootic bone; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid bone; o-Q, quadrate; o-SOp, subopercle; o-Sph, sphenotic bone.
**Figure 6.4:** The cranial lateral line system of *Ariosoma gilberti*. (a) position of the composing canals in relation to the skull (right side, lateral view) and (b) lateral view of the nasal bone, lacrimal bones and infraorbital bones (right side) (relative position of bones do not correspond to their real position). c IO, infraorbital canal; c POM, preopercular mandibular canal; c SO, supraorbital canal; c T, temporal canal; cm ST, supratemporal commissure; o-Nas, nasal bone; o-InfOrb, infraorbital bone; o-Lac, lacrimal bone.
**Figure 6.5:** Jaws of *Ariosoma gilberti* (right side) (a-b), maxillary; medial view (a), and lower jaw; medial view (b). af Md, mandibular articulation facet; af Mx-Etv, maxillo-ethmovomeral articular facet; o-Ang, angular bony complex; o-D, dentary complex; o-Mx, maxillary bone; o-CorMec, coronomeckelian bone; fs-Mec, meckelian fossa; pr Cor, coronoid process; o-ra, retroarticular bone.
Figure 6.6: Opercular series and hyoid apparatus of *Ariosoma gilberti*. (a) Opercular series; lateral view (right side) and (b) hyoid apparatus; lateral views of the anterior ceratohyal and posterior ceratohyal bones, dorsal views of urohyal, and lateral view of basihyal (right side). af Op, opercular articular facet; apo-Op, apophysis of opercle; o-BH, basihyal bone; o-CH A, anterior ceratohyal bone; o-CH P, posterior ceratohyal bone; o-Iop, interopercle; o-Op, opercle; o-POp, preopercle; o-SOp, subopercle; o-UH, urohyal bone.
Figure 6.7: Gill arches and associated muscles of *Ariosoma gilberti*. (a) Dorsal view of the ventral part and (b) ventral view of the dorsal part of the gill arch. o-Bb, basibranchial bone; o-Cb, ceratobranchial bone; o-Eb, epibranchial bone; o-Hb, hypobranchial bone; o-Ib, infrapharyngobranchial bone; o-UP, lower pharyngeal tooth plates; o-UP, upper pharyngeal tooth plates; m-Ob.d.m, medial obliquus dorsalis muscle; m-Ob.v, ventral obliquus dorsalis muscle; m-PHC, pharyngocleithralis muscle; m-Rc, rectus communis muscle; m-RD, rectus dorsalis muscle; m-RD.m, medial rectus dorsalis muscle; m-Trans.v, transversus ventralis muscle.
Figure 6.8: The cranial muscles of *Ariosoma gilberti*. (a) Skin removed (lateral view), (b) sections A2, hyohyoideus muscle complex, epaxial muscles, hypaxial muscles, ventral muscles of the head, branchiostegal rays and primordial ligament are removed (lateral view) and (c) ventral muscles of head (sagittal left cut), hyohyoideus muscle complex is removed and (d) Position of the muscles on the medial face of the suspensorium. I-CH-Ang, ceratothyalo-angular ligament; I-BH-CH, basihyal-ceratothyal ligament; I-Iop-Ang, interoperculo-angular ligament; I-prim, primordial ligament; m-A2α, ventral subsection of A2; m-A2βα, anterior part of dorsal subsection of A2β; m-A2βp, posterior part of dorsal subsection of A2β; m-A3, A3 section of the adductor mandibulae muscle complex; m-AAP, adductor arcus palatini muscle; m-AO, adductor operculi muscle; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH, hyohyoideus muscle complex; m-HH sup, hyohyoideus superior muscle; m-Hyp, hypaxial muscles; m-LAP, levator arcus palatini muscle; m-LO, levator operculi muscle; m-PH, protractor hyoidei muscle; m-SH, sternohyoideus muscle; o-BH, basihyal bone; o-D, dentary complex; o-Iop, interopercle; o-Mx, maxillary bone; o-PMx-Etv, premaxillo-ethnovomeral complex; o-PSph, parasphenoid bone; o-SOp, subopercle; o-UH, urohyal bone; t-A2, tendon of A2; t-A2β, tendon of A2β; t-A3, tendon of A3; t-DO, tendon of dilatator operculi muscle; t-LO, tendon of levator operculi; t-PH, tendon of protractor hyoidei.
**Figure 6.9:** Cranial skeleton of *Gymnothorax prasinus* (lateral view). (a) Complete skull (right side) and (b) suspensorium (right side). ac Op, opercular articular condyle; af Op, opercular articular facet; ac susp A, anterior suspensorial condyle; ac susp P, posterior suspensorial condyle; I-Q-Mx, quadrato-maxillary ligament; o-Ang, Angular bony complex; o-BSph, basisphenoid bone; o-D, dentary complex; o-F, frontal bone; o-Hm, hyomandibular bone; o-Iop, interopercle; o-Mx, maxillary bone; o-Op, opercle; o-Par, parietal bone; o-PMx-Etv, premaxillo-ethmovomeral complex; o-POp, preopercle; o-PP, palatopterygoid; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid bone; o-Q, quadrate; o-SOp, subopercle; o-Soc, supraoccipital bone; o-Sph, sphenotic bone; Op-tuberosity, opercular tuberosity.
Figure 6.10: Cranial skeleton of *Anarchias allardicei* (lateral view). (a) Complete skull (right side) and (b) suspensorium (right side). ac Op, opercular articular condyle; af Op, opercular articular facet; ac susp A, anterior suspensorial condyle; ac susp P, posterior suspensorial condyle; fr-Opt, foramen opticum; o-Ang, angular bony complex; o-BSph, basisphenoid bone; o-D, dentary complex; o-ExOc, exoccipital bone; o-F, frontal bone; o-Hm, hyomandibular bone; o-Iop, interopercle; o-Mx, maxillary bone; o-Op, opercle; o-Par, parietal bone; o-PMx-Etv, premaxillo-ethmovomeral complex; o-POp, preopercle; o-PP, palatopterygoid; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid bone; o-Q, quadrat; o-SOp, subopercle; o-Soc, supraoccipital bone; o-Sph, sphenotic bone.
Figure 6.11: Neurocranium of Gymnothorax prasinus. (a) Dorsal view and (b) ventral view. af susp A, anterior suspensorial articulation facet; af susp p, posterior suspensorial articulation facet; fr-Tri.fac, foramen trigemino-facialis; o-BOc, basioccipital bone; o-Epi, epioccipital bone; o-ExOc, exoccipital bone; o-F, frontal bone; o-Par, parietal bone; o-PMx-Etv, premaxillo-ethmovomeral complex; o-Pro, prootic bone; o-PsPh, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid; o-Soc, supraoccipital bone; o-Sph, sphenotic bone; ri-Soc, supraoccipital crest.
Figure 6.12: Neurocranium of *Anarchias allardicei*. (a) Dorsal view and (b) ventral view. af susp A, anterior suspensorial articulation facet; af susp p, posterior suspensorial articulation facet; fr-Tri.fac, foramen trigemino-facialis; o-BOc, basioccipital bone; o-BSph, basisphenoid; o-Epi, epioccipital bone; o-ExOc, exoccipital bone; o-F, frontal bone; o-Par, parietal bone; o-PMx-Etv, premaxilloethmovomeral complex; o-Pro, prootic bone; o-PSph, parasphenoid; o-Pt, pterotic bone; o-PtSph, pterosphenoid; o-Soc, supraoccipital bone; o-Sph, sphenotic bone; ri-Soc, supraoccipital crest.
**Figure 6.13:** The cranial muscles of *Gymnothorax prasinus*. (a) Skin removed (lateral view), (b) sections A2 except the subsection A2m, hyohyoideus muscle complex, hypaxial muscles, ventral elements of the head and quadrate-maxillary ligament and branchiostegal rays are removed (lateral view), (c) Ventral muscles of head (sagittal left cut), hyohyoideus muscle complex is removed. l-Q-Mx, quadrato-maxillary ligament; m-A2αl, lateral subsection of A2α; m-A2γ, medial subsection of A2; m-A3, A3 section of the adductor mandibulae muscle complex; m-AAP, adductor arcus palatini muscle; m-AH, adductor hyomandibulae muscle; m-AO, adductor operculi muscle; m-APhJ, adductor muscle of the pharyngeal jaw; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH, hyohyoideus muscle complex; m-HH sup, hyohyoideus superior muscle; m-LAP, levator arcus palatini muscle; m-Li, levator internus muscle; m-LO, levator operculi muscle; m-PH, protractor hyoidei muscle; m-RC, rectus communis muscle; m-SH, sternohyoideus muscle; o-CH A, anterior ceratohyal bone; o-CH P, posterior ceratohyal bone; o-Cl, cleithrum; o-D, dentary complex; o-ExOc, exoccipital bone; o-F, frontal bone; o-Mx, maxillary bone; o-Op, opercle; o-PMx-Etv, premaxillo-ethmovomeral complex; o-Pro, prootic bone; o-Q, quadrate bone; t-A2αl, tendon of A2αl; t-A2-Q, A2-quadrate tendon; t-A2γ, tendon of A2γ; t-A3, tendon of A3; t-Epax, tendon of epaxial muscles; t-LO, tendon of levator operculi; t-PH, tendon of protractor hyoidei; pr Cor, coronoid process.
**Figure 6.14:** Jaws of *Gymnothorax prasinus* (right side) (a-b), maxillary; lateral view (a), and lower jaw; medial view (b). af Md, mandibular articulation facet; af Mx-Etv, maxillo-ethmovomeral articular facet; o-Ang, angular bony complex; o-D, dentary complex; o-Mx, maxillary bone; fs-Mec, meckelian fossa; pr Cor, coronoid process; pr ra, retroarticular process.
Figure 6.15: Jaws of *Anarchias allardicei* (right side) (a-b), maxillary; medial view (a), and lower jaw; medial view (b). af Md, mandibular articulation facet; af Mx-Etv, maxillo-ethmovomeral articular facet; l-Pop-Ang, preoperculo-angular ligament; o-Ang, angular bony complex; o-D, dentary complex; o-CorMec, coronomeckelian bone; o-Mx, maxillary bone; fs-Mec, meckelian fossa; pr Cor, coronoid process; pr ra, retroarticular process.
**Figure 6.16:** The cranial muscles of *Anarchias allardicei*. (a) Skin removed (lateral view), (b) sections A2, hyohyoideus muscle complex, epaxial muscles, hypaxial muscles, ventral elements of the head and quadrato-maxillary ligament and branchiostegals are removed (lateral view) and (c) ventral muscles of head (sagittal left cut) and position of the pharyngeal jaws in relation to the lower jaw and hyoid apparatus, hyohyoideus muscle complex is removed. m-A2α, ventral subsection of A2; m-A2β, dorsal subsection of A2; m-A3, A3 section of the adductor mandibulare muscle complex; m-APhJ, adductor muscle of the pharyngeal jaw; m-DO, dilatator operculi muscle; m-Epax, epaxial muscles; m-HH, hyohyoideus muscle complex; m-LAP, levator arcus palatini muscle; m-LO, levator operculi muscle; m-PH, protractor hyoidei muscle; m-RC, rectus communis muscle; m-SH, sternohyoideus muscle; o-CH A, anterior ceratohyal bone; o-CH P, posterior ceratohyal bone; o-D, dentary complex; o-F, frontal bone; o-Mx, maxillary bone; o-Op, opercle; o-PMx-Etv, premaxillo-ethmocomplex; o-POp, preopercle; t-A2, tendon of A2; t-A2-Q, A2-quadrate tendon; t-A3, tendon of A3; t-DO, tendon of dilatator operculi muscle; t-LO, tendon of levator operculi; t-PH, tendon of protractor hyoidei; pr Cor, coronoid process.
Figure 6.17: The cranial lateral line system and circumorbital bones of Gymnothorax prasinus. (a) Lateral view of the nasal bone, preorbital bones, infraorbital bone, postorbital bones and supraorbital bones (right side) and (b) position of the composing canals in relation to the skull (right side, lateral view). c Adnas, adnasal canal; c Et, ethmoid canal; c IO, infraorbital canal; c POM, preopercular mandibular canal; c SO, supraorbital canal; c T, temporal canal; cm ST, supratemporal commissure; o-Nas, nasal bone; o-Adn, adnasal bone; o-InfOrb, infraorbital bone; o-Lac, lacrimal bone; o-SOrb, supraorbital bone.
Figure 6.18: The cranial lateral line system and circumorbital bones of *Anarchias allardicei*. (a) lateral view of the nasal bone, preorbital bones and postorbital bones (right side) and (b) position of the composing canals in relation to the skull (right side, lateral view). c IO, infraorbital canal; c POM, preopercular mandibular canal; c SO, supraorbital canal; c T, temporal canal; cm F, frontal commissure; cm ST, supratemporal commissure; o-Nas, nasal bone; o-InfOrb, infraorbital bone; o-Lac, lacrimal bone.
Figure 6.19: Gill arches of *Gymnothorax prasinus*. (a) Ventral view of the dorsal elements and (b) dorsal view of the ventral elements. o-Cb, ceratobranchial bone; o-Eb, epibranchial bone; o-LP, lower pharyngeal tooth plates; o-UP, upper pharyngeal tooth plates.

Figure 6.20: Gill arches of *Anarchias allardicei*. Lateral view of the ventral and dorsal part of the gill arches (right side). o-Cb, ceratobranchial bone; o-Eb, epibranchial bone; o-Ib, infrapharyngobranchial bone; o-LP, lower pharyngeal tooth plates; o-UP, upper pharyngeal tooth plates.
Figure 7.1: Cranial skeleton in *Eurypharynx pelecanoides* (Lateral view). (a) Complete scanned skull (right side), and (b) medial view the quadrato-mandibula joint (right side). c-orbito-ethmoid cartilage; (lat)Cond-Q, lateral condyle of quadrate; (med)Cond-Q, medial condyle of quadrate; l-(med)Man-Q, medial mandibulo-quadrate ligament; l-Se-Man, Sesamoid bone-mandibula ligament; o-BOc, basioccipital; o-Epi, epioccipital; o-ExOc, exoccipital; o-F, frontal; o-Hm, hyomandibula; Mand, mandibula; o-Mx, maxillary; o-Par, parietal; o-Pt, pterotic; o-Q, quadrate; o-Se, sesamoid bone; o-Sph, sphenotic; o-V, vomer; o-Ve1, first vertebra; m-Am, adductor mandibulae muscle; t-Am, tendon of the adductor mandibulae muscle.
Figure 7.2: Neurocranium of *Eurypharynx pelecanoides*. (a) Dorsal view, and (b) Ventral view. af susp, suspensorial articulation facet; c-orbito-ethmoid cartilage; fr-Mag, foramen magnum; o-BOc, basioccipital; o-Epi, epioccipital; o-ExOc, exoccipital; o-F, frontal; o-Par, parietal; o-Pro, prootic; o-PSph, parasphenoid; o-Pt, pterotic; o-Sph, sphenotic; o-V, vomer; o-Ve1, first vertebra.
**Figure 7.3:** The cranial muscles of *Eurypharynx pelecanoides*. (a) Skin removed (lateral view) and does not show entire length of the mandibula, and (b) muscles of the ventral view of neurocranium. m-AAP, adductor arcus palatini muscle; m-Am, adductor mandibulae muscle; m-AH, adductor hyomandibulae muscle; a-DM-m, anterior depressor mandibulae muscle; p-DM-m, posterior depressor mandibulae muscle; m-Epax, epaxial muscles; m-Hyp, hypaxial muscles; m-LAP, levator arcus palatini muscle; c-orbito-ethmoid cartilage; o-BOc, basioccipital; o-Epi, epioccipital; o-ExOc, exoccipital; o-F, frontal; o-Hm, hyomandibular bone; Mand, mandibula; o-Mx, maxillary bone; o-Par, parietal; o-Pro, prootic; o-Pt, pterotic; o-Q, quadrate; o-Se, sesamoid bone; o-Sph, sphenotic; o-V, vomer; o-Ve1, first vertebra; Orb, orbit; t-Am, adductor mandibulae tendon; t(vent)p.DM, ventral tendon of posterior depressor mandibulae muscle; t(dor)p.DM, dorsal tendon of posterior depressor mandibulae muscle; t(lat)Epax, lateral tendon of epaxial muscles; t-Hyp, tendon of hypaxial; t-LAP, tendon of levator arcus palatini muscle.
Figure 7.4: Histological section of the skin and bone in *Eurypharynx pelecanoides*: (a) cross section of the skin around the mouth, and (b) cross section of the hyomandibula.
Figure 7.5: Stages of supposed feeding strategy by Nielsen et al. (1989) (after Nielsen et al. 1989).
**Figure 7.6:** Stages of feeding in *Eurypharynx pelecanoides*: (a) Swimming, (b) detecting the prey and starting point of mouth opening, (c) first stage of mouth opening, (d) opened mouth at nearly a right angle, (e) moving towards the prey with the mouth opened, (f) engulfing of the prey, (g) closing mouth, (h) food items stay in the ventral pouch of the buccal cavity (after Blue planet: Eposid2 - The Deep, 2001).
Figure. 8.1. Photographs showing typical head and jaw shapes of many types of anguilliform leptocephali. These taxa are *Anguilla marmorata* (A), *Ariosoma major* (B), *Heteroconger hassi* (C), *Conger* sp. (D), *Bathycongrus* sp. (E), *Gnathophis* sp. (F), *Muraenesox cinereus* (G), *Serrivomeridae* sp. (H), *Muraenidae* sp. (I), *Chlopsidae* sp. (J), *Nettenchelys* sp. (K), and *Synaphobranchinae* sp. (L), *Ilyophinae*, *Synaphobranchidae* (M), *Eurypharynx pelecanoides* (N), *Cyema atrum* (O). (after Miller and Tsukamoto, 2004).
Figure. 8.2. Schematic illustration of the generated forces by the adductor mandibulae A2 (F2) and A2 (F3) with, respectively, their horizontal (Fh 2 and Fh 3) and vertical components (Fv 2 and Fv 3). The horizontal components run in the opposite direction, reducing the pressure in the joint between the lower jaw and the quadrate (encircled) (after De Schepper et al, 2005).