Supplementary information

Exceptional preservation reveals gastrointestinal anatomy and evolution in early actinopterygian fishes

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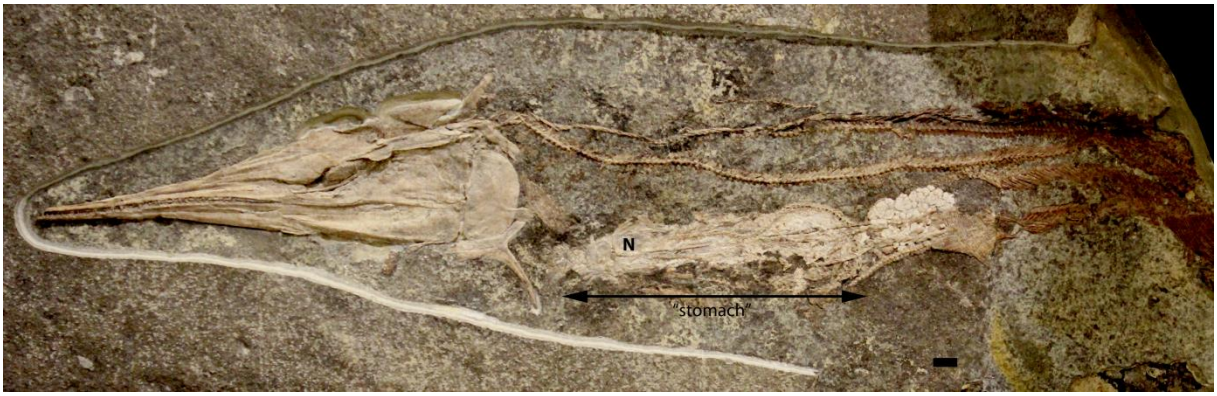
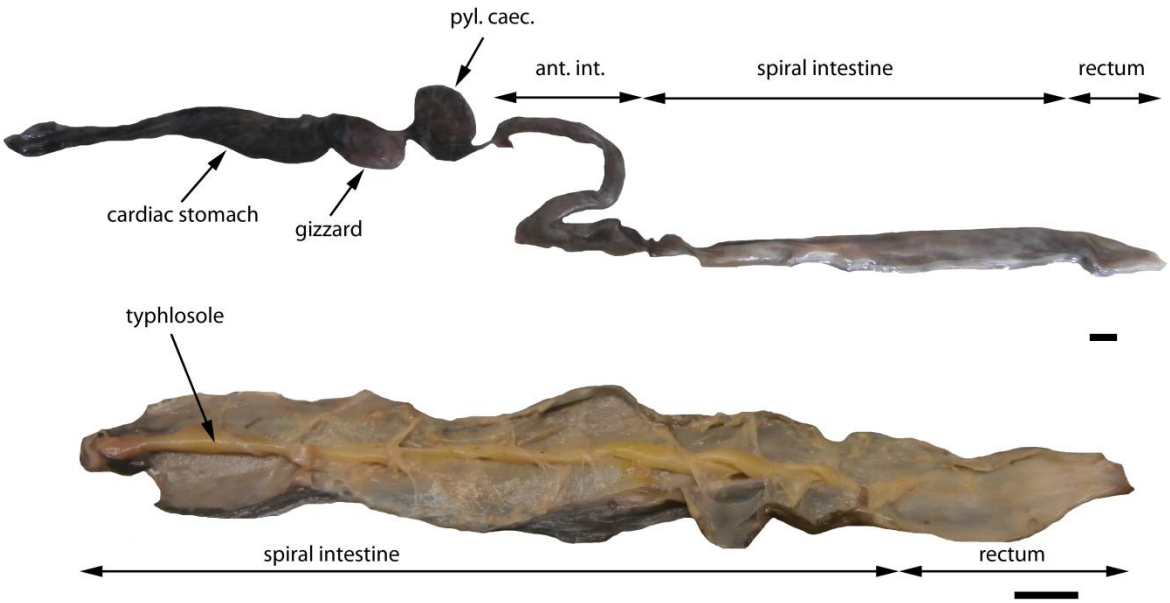
Supplementary Figure S1│ †*Saurichthys macrocephalus* (PIMUZ T 3916) detail of the preserved cololite, photographed under UV light. Scale bar equals 1 cm.

Supplementary Figure S2│ †*S. macrocephalus* (PIMUZ T 4106) with preserved straight stomach outline (stomach length is indicated by a double, black arrow) and a smaller *Saurichthys* specimen as undigested prey (N indicates the neurocranium of the prey). Scale bar equals 1 cm.

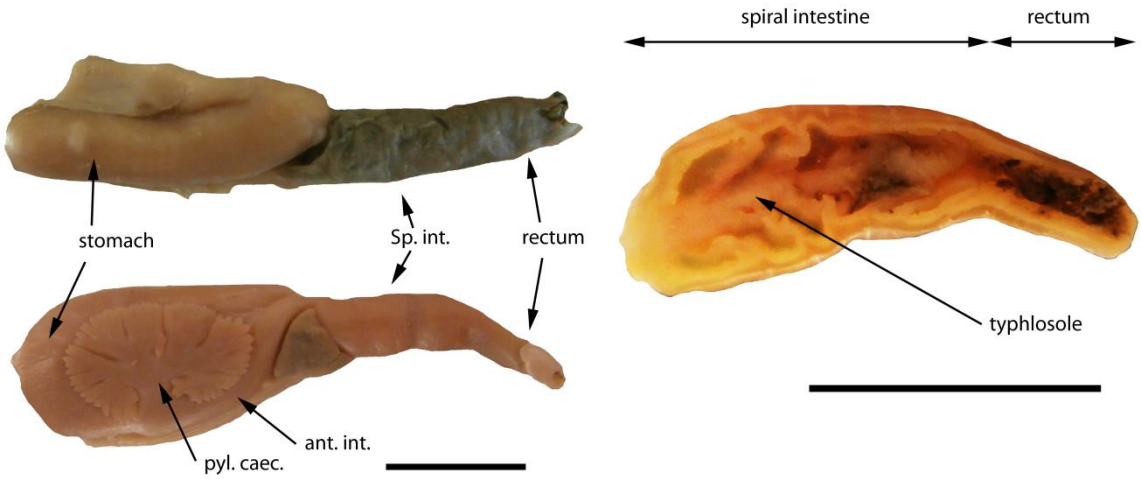


Supplementary Figure S3│ †*S. breviabdominalis* (PIMUZ T 890) exhibiting an incomplete spiral cololite. Scale bar equals 1 cm.

Supplementary Figure S4│ *Acipenser baerii* dissected GIT in ventrolateral view (top) and dissected spiral intestine (bottom), for comparison. Scale bars equal 1 cm.



Supplementary Figure S5│ *Polyodon spathula* (VIMS 12227) dissected GIT in lateral (top left) and ventral (bottom left) views and dissected spiral intestine of the same specimen (right), for comparison. Scale bars equal 1 cm.



Supplementary Note 1, on the maturity of PIMUZ T 59

We consider the examined specimen of †*S. paucitrichus* (PIMUZ T 59) to be a mature individual. The developed gonopodium, the ossifications ventral to the notochord in the abdominal region and the ossified proximal and distal radials of the unpaired fins are all in support of this view (EEM and TA pers. obs.). The validity of †*S. paucitrichus* as a species as well as the attribution of various specimens to this taxon should be revisited[1].

Supplementary Note 2, on the tree used in the PGLS analysis.

We used Mesquite[2] to construct a composite tree based on an existing molecular tree of living elasmobranchs[3]. We manually added the extant actinopterygians sensu Near et al.[4] and the sarcopterygians following the consensus presented by Nelson[5]. The placement of fossil taxa is as follows: †*Saurichthys* sensu Gardiner et al.[6]; †*Liodesmus* and †*Amblysemius*, both grouped under the "superfamily" †Caturoidea, were placed as sister taxa on the *Amia* clade, following Grande and Bemis[7]; †*Macrosemius* (†Macrosemiidae) and †*Pericentrophorus* (†Semionotidae) were placed as sister taxa on the *Lepisosteus* clade following López-Arbarello[8]; †*Eurycormus* and †*Asthenocormus* were placed on the teleost stem sensu Arratia[9].

"Order"	Species	Maximum TL (m)	Maximum turn count	References
Heterodontiformes	*Heterodontus mexicanus*	0.7	7	[10,11]
Heterodontiformes	*Heterodontus portujacksoni*	1.65	7	[10,11]
Heterodontiformes	*Heterodontus zebra*	1.25	9	[10,11]
Heterodontiformes	*Heterodontus galeatus*	1.52	7	[10,11]
Heterodontiformes	*Heterodontus francisci*	1.22	7	[10,11]
Lamniformes	*Odontaspis ferox*	4.5	32	[10,11]
Lamniformes	*Odontaspis noronhai*	3.6	32	[10,11]
Lamniformes	*Carcharias taurus*	3.2	32	[10,11]
Lamniformes	*Mitsukurina owstoni*	3.84	19	[10,11]
Lamniformes	*Pseudocarcharias kamoharai*	1.1	27	[10,11]
Lamniformes	*Megachasma pelagios*	5.49	24	[10,11]
Lamniformes	*Alopias pelagicus*	3.65	40	[10,11]
Lamniformes	*Alopias superciliosus*	4.61	45	[10,11]
Lamniformes	*Alopias vulpinus*	5.73	34	[10,11]
Lamniformes	*Cetorhinus maximus*	10	51	[10,11]
Lamniformes	*Carcharodon carcharias*	6	55	[10,11]
Lamniformes	*Isurus oxyrinchus*	4.08	54	[10,11]
Lamniformes	*Isurus paucus*	4.17	54	[10,11]
Lamniformes	*Lamna ditropis*	3.05	41	[10,11]
Lamniformes	*Lamna nasus*	3.7	41	[10,11]
Orectolobiformes	*Parascyllium colare*	0.87	9	[10,11]
Orectolobiformes	*Brachaelurus waddi*	1.22	11	[10,11]
Orectolobiformes	*Brachaelurus cocloughi*	0.75	11	[10,11]
Orectolobiformes	*Eucrossorhinus dasypogon*	1.25	33	[10,11]
Orectolobiformes	*Orectolobus maculatus*	3.2	25	[10,11]
Orectolobiformes	*Orectolobus ornatus*	2.88	23	[10-12]
Orectolobiformes	*Orectolobus parvimaculatus*	0.88	28	[10,11,13]
Orectolobiformes	*Orectolobus halei*	2	32	[10-12]
Orectolobiformes	*Orectolobus floridus*	0.75	25	[10,11,13]
Orectolobiformes	*Orectolobus hutchinsi*	1.49	28	[10,11,14]
Orectolobiformes	*Chiloscyllium griseum*	0.77	19	[10,11]
Orectolobiformes	*Chiloscyllium hasseltii*	0.61	15	[10,11]
Orectolobiformes	*Chiloscyllium indicum*	0.65	15	[10,11]
Orectolobiformes	*Chiloscyllium plagiosum*	0.95	17	[10,11]
Orectolobiformes	*Chiloscyllium punctatum*	1.05	20	[10,11]
Orectolobiformes	*Stegostoma fasciatum*	3.54	18	[10,11]
Orectolobiformes	*Ginglimostoma cirratum*	4.3	17	[10,11]
Orectolobiformes	*Nebrius ferrugineous*	3.2	24	[10,11]
Orectolobiformes	*Pseudoginglymostoma brevicaudatum*	0.75	15	[10,11]
Orectolobiformes	*Rhincodon typus*	21	74	[10,11]
Carcharhiniformes	*Apristurus profundorum*	0.54	10	[10,15]
Carcharhiniformes	*Apristurus ampliceps*	0.85	11	[10]
Carcharhiniformes	*Scyliorhinus canicula*	1	11	[10,16]

Carcharhiniformes	*Scyliorhinus capensis*	1.22	11	[10,16]
Carcharhiniformes	*Scyliorhinus retifer*	0.47	11	[10,16]
Carcharhiniformes	*Scyliorhinus stellaris*	1.62	11	[10,16]
Carcharhiniformes	*Cephaloscyllium ventriosum*	1	12	[10,16]
Carcharhiniformes	*Poroderma africanum*	1.01	13	[10,16]
Carcharhiniformes	*Poroderma pantherinum*	0.84	13	[10,16]
Carcharhiniformes	*Asymbolus analis*	0.61	9	[10,16]
Carcharhiniformes	*Galeus arae*	0.36	14	[10,16]
Carcharhiniformes	*Galeus sauteri*	0.38	14	[10,16]
Carcharhiniformes	*Galeus polli*	0.3	14	[10,16]
Carcharhiniformes	*Galeus melastomus*	0.9	14	[10,16]
Carcharhiniformes	*Galeus murinus*	0.63	14	[10,16]
Carcharhiniformes	*Halaelurus lineatus*	0.56	10	[10,16]
Carcharhiniformes	*Halaelurus natalensis*	0.47	10	[10,16]
Carcharhiniformes	*Halaelurus buergeri*	0.49	10	[10,16]
Carcharhiniformes	*Haploblepharus edwardsii*	0.6	8	[10,16]
Carcharhiniformes	*Holohalaelurus regani*	0.61	7	[10,16]
Carcharhiniformes	*Parmaturus xaniurus*	0.45	8	[10,16]
Carcharhiniformes	*Eridacnis*	2	8	[10,16]
Carcharhiniformes	*Gollum attenuatus*	1.07	11	[10,16]
Carcharhiniformes	*Pseudotriakis microdon*	2.95	17	[10,16]
Carcharhiniformes	*Leptocharias smithii*	0.77	16	[10,16]
Carcharhiniformes	*Furgaleus macki*	1.6	7	[10,16]
Carcharhiniformes	*Galeorhinus galeus*	1.93	5	[10,16]
Carcharhiniformes	*Hemitriakis japanica*	1.2	8	[10,16]
Carcharhiniformes	*Hemitriakis leucoperiptera*	0.96	7	[10,16]
Carcharhiniformes	*Hypogaleus hyugaensis*	1.27	6	[10,16]
Carcharhiniformes	*Iago omanensis*	0.37	5	[10,16]
Carcharhiniformes	*Iago garricki*	0.75	6	[10,16]
Carcharhiniformes	*Mustelus asterias*	1.4	8	[10,16]
Carcharhiniformes	*Mustelus californicus*	1.16	8	[10,16]
Carcharhiniformes	*Mustelus canis*	1.5	9	[10,16]
Carcharhiniformes	*Mustelus henlei*	1	8	[10,16]
Carcharhiniformes	*Mustelus lenticulatus*	1.25	8	[10,16]
Carcharhiniformes	*Mustelus lunulatus*	1.7	9	[10,16]
Carcharhiniformes	*Mustelus manazo*	2.2	9	[10,16]
Carcharhiniformes	*Mustelus norrisi*	1.1	9	[10,16]
Carcharhiniformes	*Scylliogaleus quecketti*	0.89	7	[10,16]
Carcharhiniformes	*Triakis megalopterus*	1.42	6	[10,16]
Carcharhiniformes	*Triakis scyllium*	1.5	8	[10,16]
Carcharhiniformes	*Triakis semifasciata*	1.98	8	[10,16]
Carcharhiniformes	*Hemipristis elongatus*	2.4	6	[10,16]
Carcharhiniformes	*Hemigaleus microstoma*	1.14	6	[10,16]
Carcharhiniformes	*Paragaleus pectoralis*	1.4	6	[10,16]
Squaliformes	*Echinorhinus brucus*	3.1	16	[10,17]
Squaliformes	*Squalus acanthias*	1.6	13	[10,17]

Squaliformes	*Squalus suckleyi*	1.3	13	10,18
Squaliformes	*Squalus brevirostris*	0.6	9	10,19
Squaliformes	*Centrophorus granulosus*	1.7	14	10,17
Squaliformes	*Centrophorus lusitanicus*	1.6	13	10,17
Squaliformes	*Centrophorus squamosus*	1.64	14	10,17
Squaliformes	*Deania profundorum*	0.88	25	10,20
Squaliformes	*Centroscyllium fabricii*	0.7	10	10,17
Squaliformes	*Etmopterus gracilispinis*	0.35	11	10,21
Squaliformes	*Etmopterus bigelowi*	0.67	19	10,22
Squaliformes	*Etmopterus pussilus*	0.5	13	10,22
Squaliformes	*Etmopterus unicolor*	0.64	12	10,23
Squaliformes	*Etmopterus granulosus*	0.6	13	10,23
Squaliformes	*Centroscymnus coelolepis*	1.22	21	10,17
Squaliformes	*Centroscymnus owstoni*	1.2	15	10,17
Squaliformes	*Somniosus microcephalus*	7.3	34	10,17
Squaliformes	*Somniosus rostratus*	1.43	29	10,24
Squaliformes	*Somniosus pacificus*	4.4	37	10,24
Squaliformes	*Zameus squamulosus*	0.84	16	10,17
Squaliformes	*Oxynotus*	1.5	11	10,17
Squaliformes	*Isistius brasiliensis*	0.42	10	10
Squaliformes	*Squaliolus laticaudus*	0.28	13	10,17
Pristiophoriformes	*Pristiophorus nancyae*	0.62	7	10,25
Pristiophoriformes	*Pristiophorus lanae*	0.83	6	10,26
Squatiniformes	*Squatina*	2.44	12	10,17
Hexanchiformes	*Chlamydoselachus anguineus*	1.96	49	10,17
Hexanchiformes	*Heptranchias perlo*	1.39	22	10,17
Hexanchiformes	*Heptranchias griseus*	5.5	39	10,17
Hexanchiformes	*Heptranchias nakamurai*	1.8	28	10,17
Ceratodontiformes	*Neoceratodus forsteri*	1.7	9	10,27
Ceratodontiformes	*Protopterus annectens*	1	6	10,28
Polypteriformes	*Polypterus*	0.97	6	10,28
Polypteriformes	*Erpetoichthys calabaricus*	0.37	7	10,29
Acipenseriformes	*Polyodon spathula*	2.21	6	10,30, pers. obs.
Acipenseriformes	*Acipenser baerii*	2	8	10,31, pers. obs.
Acipenseriformes	*Acipenser transmontanus*	6.1	8	10,31, pers. obs.
Acipenseriformes	*Scaphirhynchus*	2	5	10,32
incerta	†*Saurichthys paucitrichus*	0.26	30	pers. obs.
Lepisosteiformes	*Lepisosteus osseus*	2	2	10,33, pers. obs.
†Semionotiformes	†*Pericentrophorus minimus*	0.04	8	34,35
†Semionotiformes	†*Macrosemius rostratus*	0.26	4	36,37
Amiiformes	*Amia calva*	1.09	4	10,38
Amiiformes	†*Amblysemius pachyurus*	0.26	17	37,39
Amiiformes	†*Liodesmus gracilis*	0.13	7	37,39
†Pachycormiformes	†*Asthenocormus titanius*	2.34	73	37,40
incerta	†*Eurycormus speciosus*	0.19	13	37,41

Supplementary Table 1 | Spiral valve turn count and maximum TLs of extant elasmobranch, sarcopterygian and actinopterygian taxa, and †*Saurichthys paucitrichus*, included in the regression analyses.

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