PNAS
www.pnas.org

Supplementary Information for

Fin ray patterns at the fin to limb transition

Thomas A. Stewart, Justin B. Lemberg, Natalia K. Taft, Ihna Yoo, Edward B. Daeschler, Neil H. Shubin

Corresponding authors: Thomas A. Stewart, Neil H. Shubin
Email: Thomas A. Stewart, tomstewart@uchicago.edu; Neil H. Shubin, nshubin@uchicago.edu

This PDF file includes:

Other supplementary materials for this manuscript include the following:

www.pnas.org/cgi/doi/10.1073/pnas.1915983117

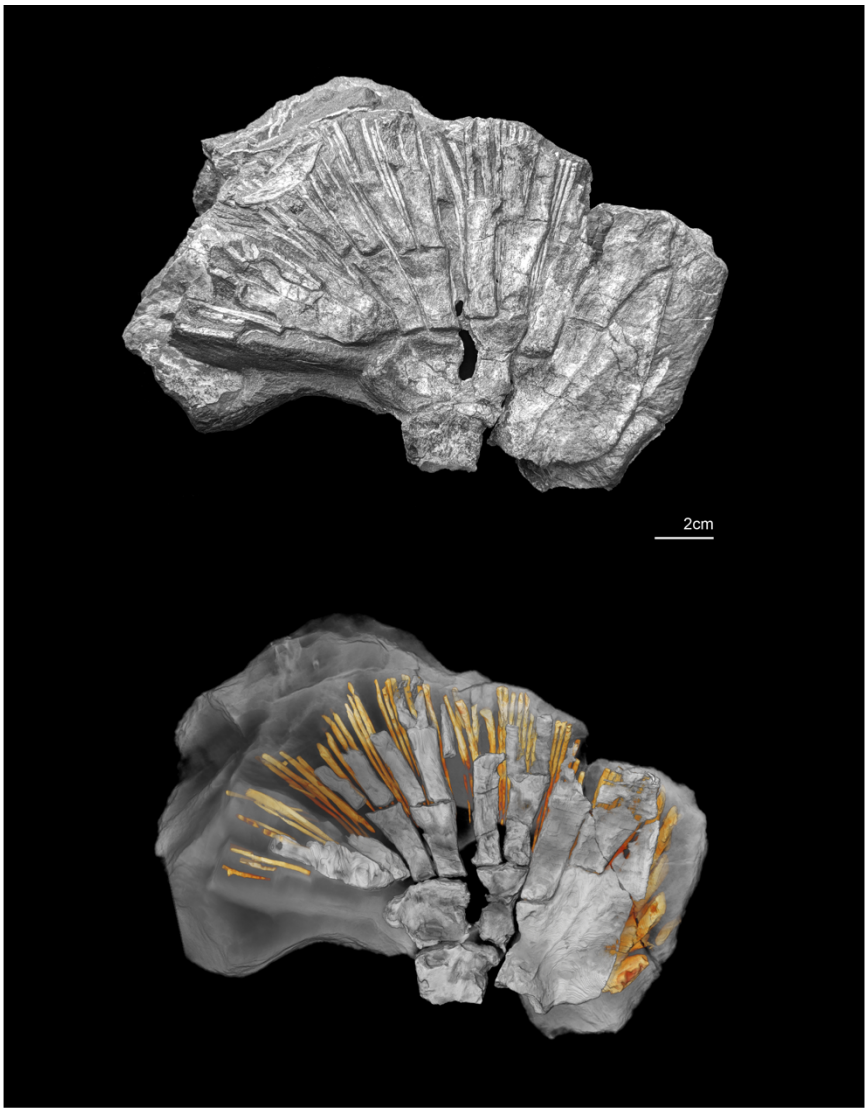

Fig. S1. Photograph and volume rendering of the right pectoral fin of *Sauripterus taylori*, ANSP20581.

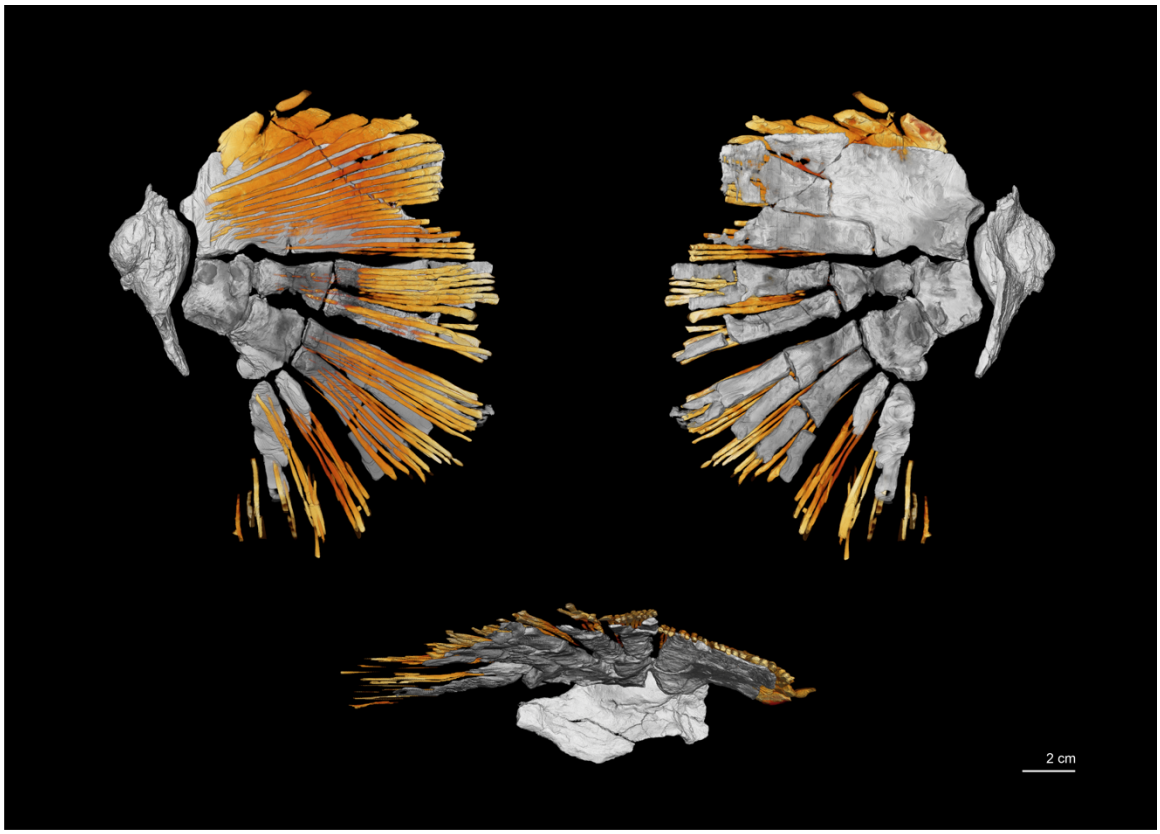

Fig. S2. Reconstruction of the right pectoral fin of *Sauripterus taylori*, ANSP20581.

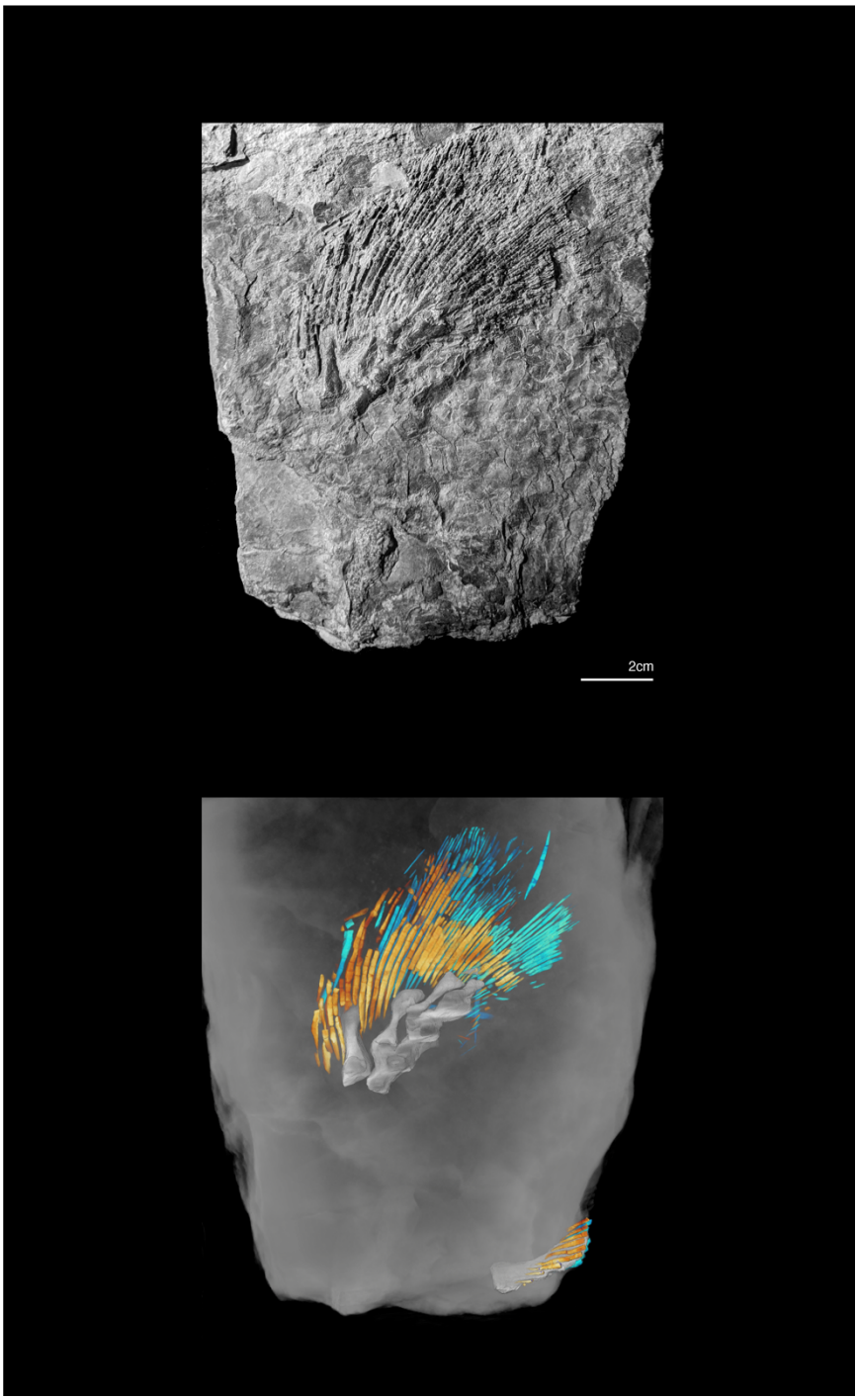

Fig. S3. Photograph and volume rendering of the pectoral fins of *Eusthenopteron foordi,* CMNH 8153.

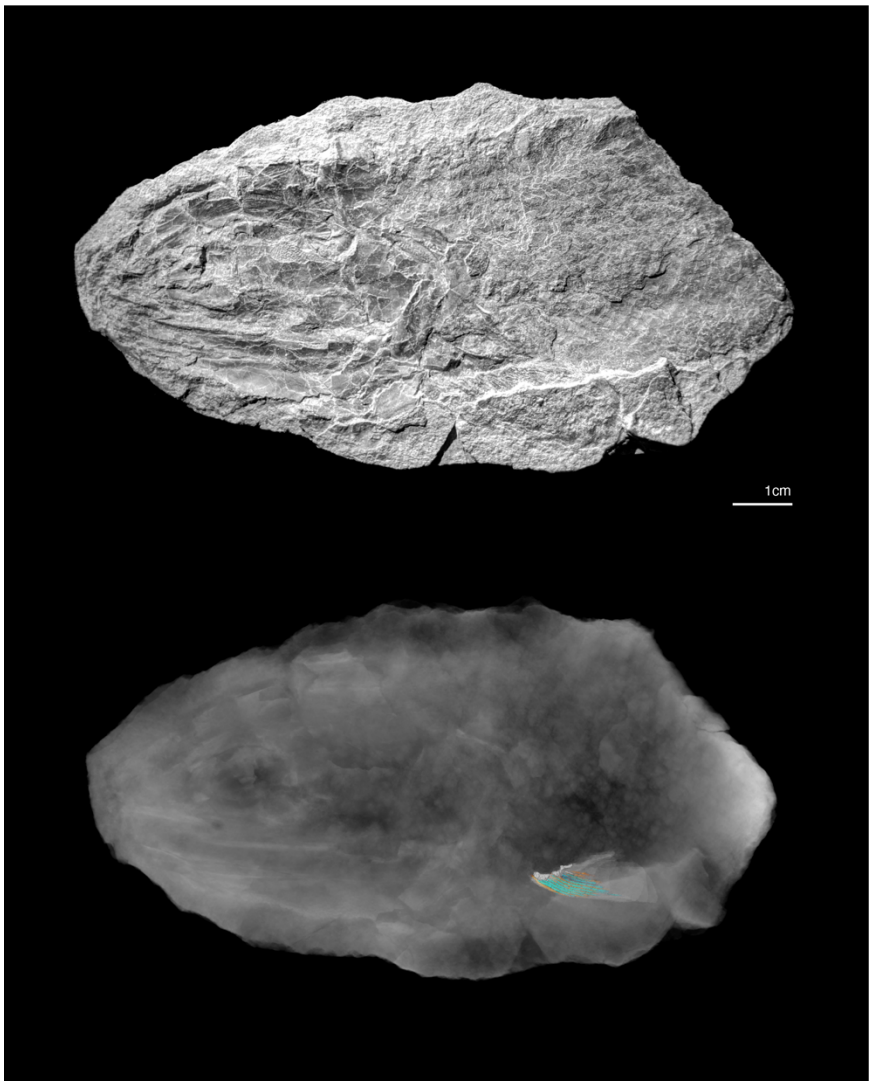

Fig. S4. Photograph and volume rendering of the pectoral fins of *Eusthenopteron foordi,* CMNH 10926.

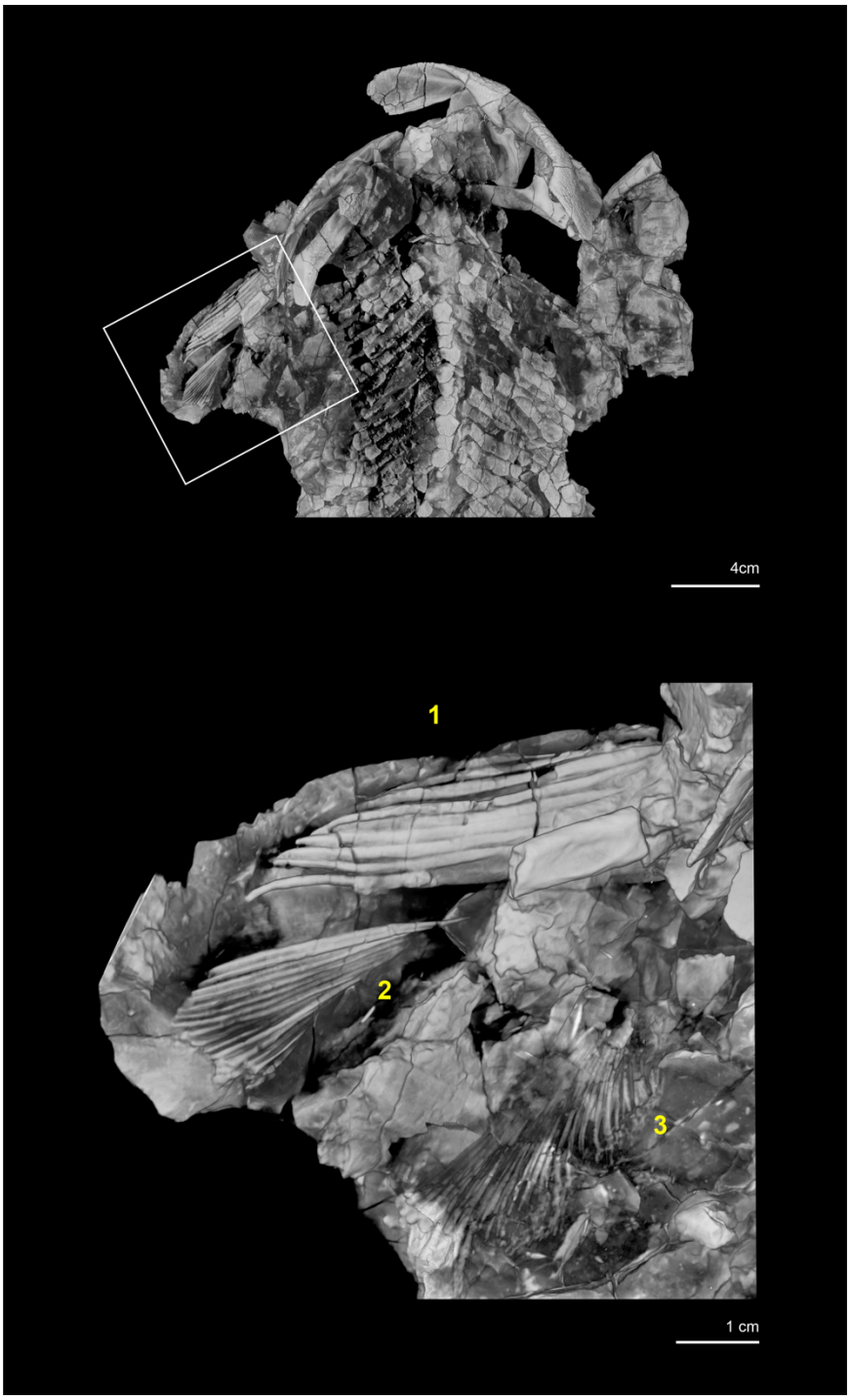

Fig. S5. Pectoral fin rays of *Tiktaalik roseae*, NUFV108. (A) Volumetric rendering of the specimen, which is exposed in dorsal aspect. The left pectoral fin is marked by a white rectangle. Anterior is towards the top. (B) Magnified view of the left pectoral fin. Matrix covering the posterior portion of the fin has been digitally removed. Dermal rays are separated into three groups: (1) rays dorsal to

the radius, (2) distal rays that are expected to have covered the distal fin, and (3) the most posterior group showing a distal fringe.

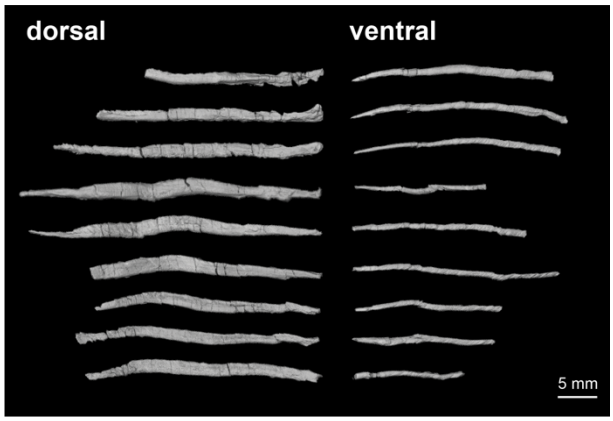

Fig. S6. Dorsal and ventral hemitrichia from *Tiktaalik roseae*, NUFV109, showing dorsoventral asymmetry. The rows are hemitrichia diagnosed as pairs.

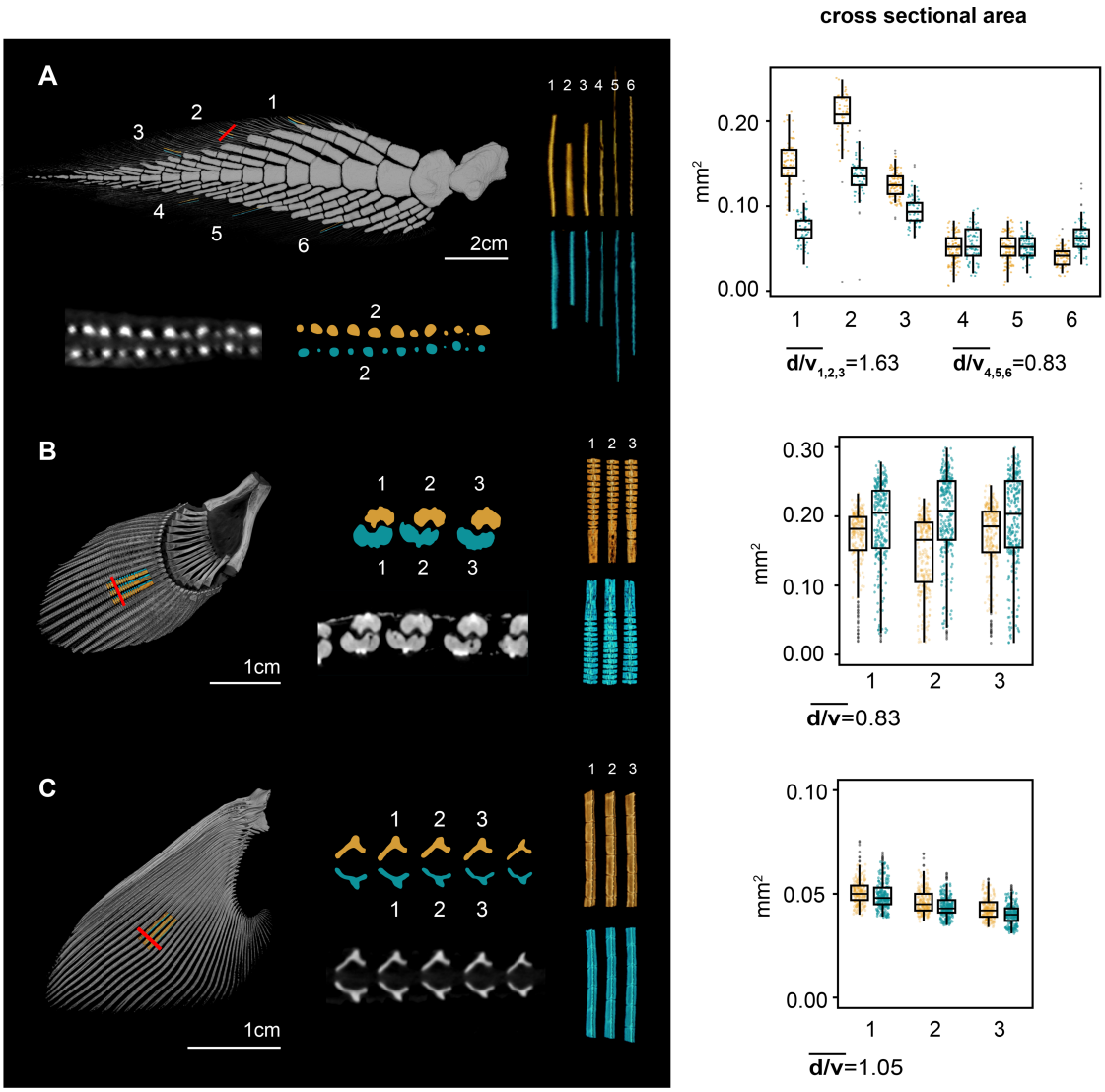

Fig. S7. Comparisons of dorsal and ventral dermal rays in the pectoral fins of *Neoceratodus*, *Polypterus*, and *Acipenser*. (A) Right pectoral fin of *Neoceratodus* (MCZ157440). (B) The right pectoral fin of *Polypterus* (FMNH1217440). (C) The left pectoral fin of *Acipenser* (FMNH144017). For all fins, cross sectional area (CSA) was calculated for pairs of dermal rays. The rays analyzed are numbered from anterior to posterior. Volumetric renderings of the fins indicate the position of the rays that analyzed and also the position of the cross section (denoted by a red line) that is figured and illustrated. For both volumetric renderings and box plots, the color orange-yellow designates dorsal hemitrichia and the color cyan designates ventral hemitrichia. The mean ratios of dorsal to ventral rays CSAs are reported

as the variable “d/v.” Box plots show median value, the first and third quartile, and maximum and minimum values; outlying points are denoted as grey dots.

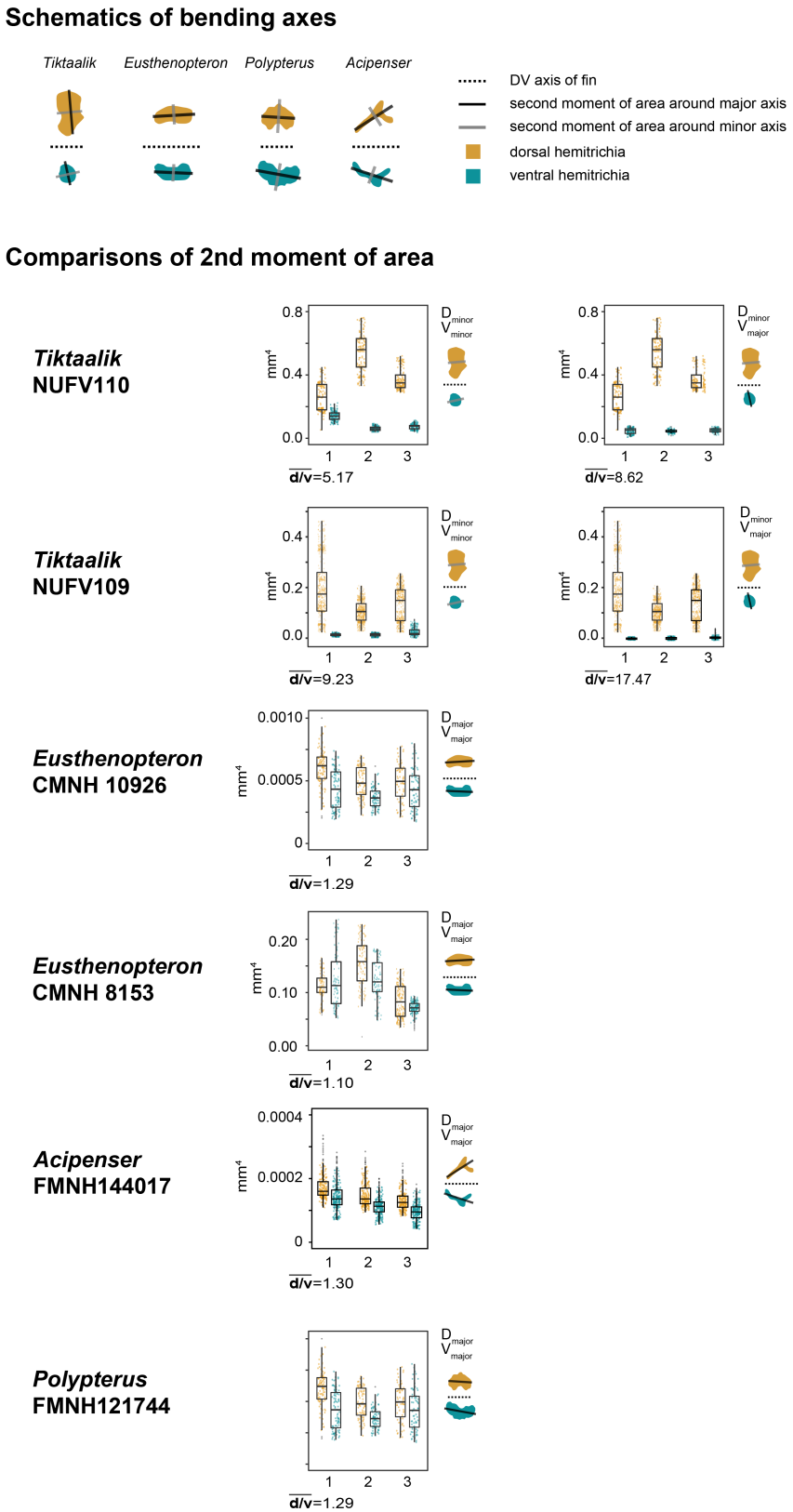

Fig. S8. Comparisons of second moment of area of dorsal and ventral hemitrichia. Schematics show a representative lepidotrichial cross section for each species (taken from Figs 5, S7). For

each pair, the hemitrichia have been maintained in their original orientation relative to one another. A dashed line shows the estimated dorsoventral (DV) axis of the fin. The position and orientation of SMAs around major and minor axes for the representative cross sections are illustrated. To compare SMA of dorsal and ventral hemitrichia in the fin's DV axis, we identified the axis (major or minor) most closely aligned with the DV axis; these comparisons are presented in the left column. To assess the impact of alternative orientations of the ventral rays in *Titkaalik* comparisons were repeated with the alternative axis of bending (*i.e.*, for ventral rays considering SMA around the major axis). The mean ratios of dorsal to ventral hemitrichial SMAs for the three lepidotrichia of each fin are reported as the variable "d/v." Box plots show median value, the first and third quartile, and maximum and minimum values; outlying points are denoted in as grey dots. In schematics and box plots, the color orange-yellow designates dorsal hemitrichia and the color cyan designates ventral hemitrichia. For all but one of the pairwise comparisons of dorsal and ventral hemitrichia of a lepidotrichia, hemitrichia differ in SMA (Mann–Whitney U test, p value < 0.05) (Table S2). The exception is lepidotrichium 1 of CMNH10926.

Table S1. Computed tomography scanning parameters and specimen information.

taxon	specimen	description	scanner	voltage (kV)	current (uA)	timing (ms)	voxel size (um)	filter (mm)
Sauripterus taylori	ANSP20581	right pectoral fin minus humerus, ventral surface exposed and ventral rays removed	GE Phoenix v|tome|x (240 tube)	90	280	1000	106.199	0.1 Cu
Sauripterus taylori	ANSP20581	humerus of right pectoral fin	GE Phoenix v|tome|x (240 tube)	110	250	1000	29.553	0.3 Cu
Eusthenopteron foordi	CMNH8153	left and right pectoral fins and girdle in a slab	GE Phoenix v|tome|x (240 tube)	90	400	1000	70.012	na
Eusthenopteron foordi	CMNH10926	slab specimen containing a whole animal laterally compressed, broken into two pieces	GE Phoenix v|tome|x (240 tube)	90	300	1000	36.747	na
Tiktaalik roseae	NUFV109	distal tip of right pectoral fin	GE Phoenix v|tome|x (240 tube)	100	370	500	37.716	0.12 Cu
Tiktaalik roseae	NUFV110	nearly complete articulated right pectoral fin	GE Phoenix v|tome|x (240 tube)	90	280	1000	54.158	0.12 Cu
Tiktaalik roseae	NUFV108	Contains left pectoral fin, pectoral girdle, dorsal scales	GE Phoenix v|tome|x (240 tube)	100	570	500	122.441	0.24 Cu
Neoceratodus forsteri	MCZ157440	right pectoral fin	HMXST225	75	140	1000	101.9325	na
Polypterus ornatipinnus	FMNH 1217440	right pectoral fin, skeletonized	GE Phoenix v|tome|x (240 tube)	70	170	333	24.4	na
Acipenser brevirostrum	FMNH 144017	left pectoral fin	HMXST225	65	150	1000	18.631	na

Table S2. Results of Mann–Whitney U tests comparing dorsal and ventral rays' CSA and SMA in dorsoventral axis.

taxon	specimen	rays compared	value	W	*p* value
Tiktaalik	NUFV110	d1_vs_v1	csa	13274	3.25E-26
Tiktaalik	NUFV110	d2_vs_v3	csa	15494	2.36E-42
Tiktaalik	NUFV110	d2_vs_v3	csa	16254	2.39E-43
Tiktaalik	NUFV110	d1_vs_v1	sma	13604	3.61E-29
Tiktaalik	NUFV110	d2_vs_v3	sma	15494	1.29E-42
Tiktaalik	NUFV110	d2_vs_v3	sma	16254	1.22E-43
Tiktaalik	NUV109	d1_vs_v1	csa	281936	4.68E-175
Tiktaalik	NUV109	d2_vs_v3	csa	309000	1.17E-182
Tiktaalik	NUV109	d2_vs_v3	csa	275706	6.43E-157
Tiktaalik	NUV109	d1_vs_v1	sma	281923	3.90E-175
Tiktaalik	NUV109	d2_vs_v3	sma	309000	1.01E-182
Tiktaalik	NUV109	d2_vs_v3	sma	273260.5	2.36E-151
Eusthenopteron	CMNH10926	d1_vs_v1	csa	6190.5	0.00078785
Eusthenopteron	CMNH10926	d2_vs_v3	csa	3892.5	0.00255005
Eusthenopteron	CMNH10926	d2_vs_v3	csa	3454.5	7.19E-08
Eusthenopteron	CMNH10926	d1_vs_v1	sma	7536.5	1.81E-11
Eusthenopteron	CMNH10926	d2_vs_v3	sma	4761.5	1.09E-09
Eusthenopteron	CMNH10926	d2_vs_v3	sma	2737.5	0.02840708
Eusthenopteron	CMNH8153	d1_vs_v1	csa	26857	3.69E-08
Eusthenopteron	CMNH8153	d2_vs_v2	csa	6860	3.71E-05
Eusthenopteron	CMNH8153	d3_vs_v3	csa	6815.5	1.09E-16
Eusthenopteron	CMNH8153	d1_vs_v1	sma	23688.5	0.0050361
Eusthenopteron	CMNH8153	d2_vs_v2	sma	7232	5.30E-07
Eusthenopteron	CMNH8153	d3_vs_v3	sma	4499	0.2252802
Polypterus	FMNH121744	d1_vs_v1	csa	24302	8.68E-08
Polypterus	FMNH121744	d2_vs_v2	csa	17777.5	5.36E-22
Polypterus	FMNH121744	d3_vs_v3	csa	25140.5	5.41E-17
Polypterus	FMNH121744	d1_vs_v1	sma	31026	0.16390405
Polypterus	FMNH121744	d2_vs_v2	sma	21005	6.75E-15
Polypterus	FMNH121744	d3_vs_v3	sma	31858	1.41E-11
Acipenser	FMNH144017	d1_vs_v1	csa	28600	0.00182856
Acipernser	FMNH144017	d2_vs_v2	csa	30235	1.42E-05
Acipenser	FMNH144017	d3_vs_v3	csa	32506.5	2.47E-27
Acipenser	FMNH144017	d1_vs_v1	sma	35559.5	1.08E-16
Acipenser	FMNH144017	d2_vs_v2	sma	38261	6.36E-25
Acipenser	FMNH144017	d2_vs_v2	sma	40992	2.27E-47

Neoceratodus	MCZ157440	d1_vs_v1	csa	4586.5	2.92E-23
Neoceratodus	MCZ157440	d2_vs_v2	csa	2492.5	1.17E-15
Neoceratodus	MCZ157440	d3_vs_v3	csa	6514	3.02E-18
Neoceratodus	MCZ157440	d4_vs_v4	csa	2906	0.08502689
Neoceratodus	MCZ157440	d5_vs_v5	csa	4761.5	0.12736218
Neoceratodus	MCZ157440	d6_vs_v6	csa	687	9.13E-19

Movie S1 (separate file). NUFV110, *Tiktaalik roseae,* pectoral fin with repositioning of endoskeleton.

Movie S2 (separate file). NUFV109, *Tiktaalik roseae,* pectoral fin tip.

Movie S3 (separate file). ANSP20581, *Sauripterus taylori* pectoral fin with repositioning of endoskeleton.

3-dimensional image (separate file). NUFV110, *Tiktaalik roseae*, dermal fin rays and endoskeleton of the pectoral fin.