

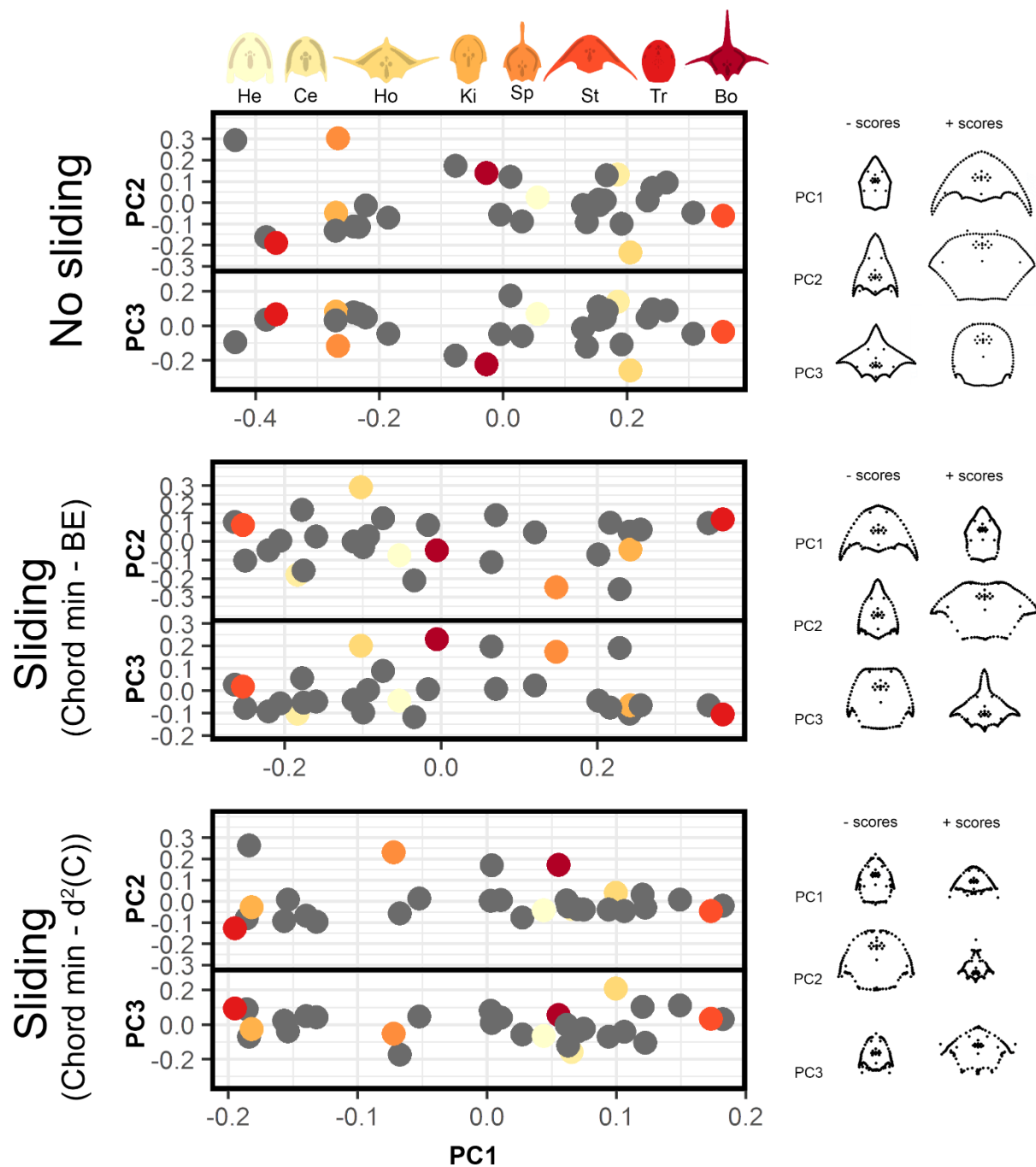
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## **Supplemental Information**

### **Computational Fluid Dynamics Suggests**

### **Ecological Diversification among Stem-Gnathostomes**

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**Figure S1. Principal component analysis graphs derived from Procrustes superimposition without semi-landmark sliding and using two different sliding methods (minimum bending energy, Chord min – BE; and minimum Procrustes distance, Chord min  $d^2(C)$ ). Related to STAR Methods.**

Species	Specimen number	Location	Deformation
<i>Acrotomaspis instabilis</i>	P54412(415a)	NHM	Possibly some but confined to the non-digitize side of the head shield
<i>Auchenaspis egertoni</i>	P6112	NHM	Slight deformation of the back of the head shield
<i>Belonaspis puella</i>	1081II	MNHM	-
<i>Benneviaspis holtedahli</i>	29879	PMO	-
<i>Benneviaspis lankesteri</i>	4687	NHM	-
<i>Boreaspis macrorhynchus</i>	29829	PMO	-
<i>Cephalaspis lyelli</i>	P6945	NHM	-
<i>Dartmuthia gemmifera</i>	P24990	NHM	-
<i>Dicranaspis gracilis</i>	33578(277)	PMO	Some shearing
<i>Didymaspis grindrodi</i>	30486	OUMNH	-
<i>Ectinaspis heintzi</i>	P40173	NHM	-
<i>Hemicyclaspis murchisoni</i>	P8811	NHM	-
<i>Hildenaspis</i> sp.	1166	MNHM	Possibly some but confined to the non-digitize side of the head shield
<i>Hoelaspis angulata</i>	24896	PMO	-
<i>Kiaeraspis auchenaspidoides</i>	Reconstruction in Stensio [S1]: fig. 3		-
<i>Mimetaspis hoeli</i>	30046	PMO	-
<i>Norselaspis glacialis</i>	1027	MNHM	-
<i>Oeselaspis pustulata</i>	9221	AMNH	-
<i>Procephalaspis oeselensis</i>	12972	AMNH	-
<i>Saaremaspis mickwitzii</i>	11423(T283)-9551	AMNH	Slight deformation of the back of the head shield
<i>Securiaspis kitchini</i>	P4115	NHM	-
<i>Spatulaspis robustus</i>	P54492(42)a	NHM	-
<i>Stensiopelta pustulata</i>	P20554	NHM	-
<i>Tegaspis kollerii</i>	P40198	NHM	-
<i>Thyestes verrucosus</i>	12770	AMNH	-
<i>Tremataspis schmidtii</i>	P60567-12157	NHM	-
<i>Waengsjoeaspis excellens</i>	P54347(518a)	NHM	-
<i>Witaaspis schrenkii</i>	11226-12714	AMNH	-
<i>Wladysagitta janvieri</i>	P9763	NHM	-
<i>Zenaspis salweyi</i>	P19227	NHM	Possibly some along the back of the head shield

**Table S2. List of species and specimens used in the geometric morphometric analysis with information about their location, registration number and details of any post-mortem deformation. Related to STAR Methods.** Institutional abbreviations: AMNH, American Museum of Natural History, New York, NY, USA; MNHM, Museum National d'Histoire Naturelle, Paris, France; NHM, Natural History Museum, London, UK; OUMNH, Oxford

University Museum of Natural History, Oxford, UK; PMO, Naturhistorisk Museum (Paleontologi), University of Oslo, Norway.

Sliding (Chord – min d <sup>2</sup> (C))				Sliding (Chord – min BE)				No sliding			
PC	SV	%	Cum %	PC	SV	%	Cum %	PC	SV	%	Cum %
1	0.64037	36.41%	36.41%	1	1.03647	48.56%	48.56%	1	1.24403	58.76%	58.76%
2	50.31%	22.47%	58.88%	2	0.70075	22.20%	70.76%	2	0.70404	18.82%	77.58%
3	45.99%	18.78%	77.66%	3	0.55591	14.13%	84.89%	3	0.57683	12.63%	90.21%
4	22.45%	4.47%	82.13%	4	0.2932	3.89%	88.78%	4	0.31049	3.66%	93.87%
5	19.82%	3.49%	85.61%	5	0.27608	3.45%	92.22%	5	0.22066	1.85%	95.72%
6	18.34%	2.99%	88.60%	6	0.22734	2.34%	94.56%	6	0.18638	1.32%	97.04%
7	14.45%	1.85%	90.46%	7	0.1898	1.63%	96.19%	7	0.14041	0.75%	97.79%
8	14.04%	1.75%	92.20%	8	0.14441	0.94%	97.13%	8	0.1177	0.53%	98.31%
9	12.85%	1.47%	93.67%	9	0.13463	0.82%	97.95%	9	0.10974	0.46%	98.77%
10	11.41%	1.16%	94.83%	10	0.12735	0.73%	98.68%	10	0.08654	0.28%	99.06%
11	9.74%	0.84%	95.67%	11	0.08559	0.33%	99.02%	11	0.07622	0.22%	99.28%
12	8.77%	0.68%	96.35%	12	0.0701	0.22%	99.24%	12	0.06363	0.15%	99.43%
13	8.11%	0.58%	96.94%	13	0.05948	0.16%	99.40%	13	0.0529	0.11%	99.54%
14	7.72%	0.53%	97.46%	14	0.04696	0.10%	99.50%	14	0.04893	0.09%	99.63%
15	6.80%	0.41%	97.88%	15	0.045	0.09%	99.59%	15	0.04446	0.08%	99.70%
16	6.25%	0.35%	98.22%	16	0.0432	0.08%	99.67%	16	0.0397	0.06%	99.76%
17	5.46%	0.27%	98.49%	17	0.03641	0.06%	99.73%	17	0.03606	0.05%	99.81%
18	5.30%	0.25%	98.74%	18	0.0343	0.05%	99.79%	18	0.03218	0.04%	99.85%
19	5.10%	0.23%	98.97%	19	0.03032	0.04%	99.83%	19	0.02843	0.03%	99.88%
20	4.71%	0.20%	99.17%	20	0.02774	0.03%	99.86%	20	0.02836	0.03%	99.91%
21	4.41%	0.17%	99.34%	21	0.02494	0.03%	99.89%	21	0.0239	0.02%	99.93%
22	3.90%	0.14%	99.47%	22	0.02183	0.02%	99.91%	22	0.01956	0.01%	99.95%
23	3.79%	0.13%	99.60%	23	0.02069	0.02%	99.93%	23	0.01876	0.01%	99.96%
24	3.51%	0.11%	99.71%	24	0.01907	0.02%	99.95%	24	0.01688	0.01%	99.97%
25	2.95%	0.08%	99.79%	25	0.01826	0.02%	99.96%	25	0.01509	0.01%	99.98%
26	2.88%	0.07%	99.86%	26	0.0164	0.01%	99.98%	26	0.01255	0.01%	99.99%
27	2.49%	0.05%	99.92%	27	0.01602	0.01%	99.99%	27	0.01125	0.00%	99.99%
28	2.28%	0.05%	99.96%	28	0.01268	0.01%	99.99%	28	0.01061	0.00%	100.00%
29	2.06%	0.04%	100.00%	29	0.01147	0.01%	100.00%	29	0.00919	0.00%	100.00%

**Table S3. Principal component analysis results (proportions of explained and cumulative explained variance) derived from Procrustes superimposition without semi-landmark sliding and using two different sliding methods (minimum bending energy, Chord min – BE; and minimum Procrustes distance, Chodr min d<sup>2</sup>(C)). Related to STAR Methods.**

Taxa	Total length (cm)	Shield surface area (mm <sup>2</sup> )	Source for 3D reconstruction
<i>Hoelaspis angulata</i>	6.5	260.156	[S1,S2]
<i>Tremataspis schmidtii</i>	7.5	750.630	[S3]
<i>Kiaeraspis auchenaspidoides</i>	5.7	299.445	[S2]
<i>Hemicyclaspis murchisoni</i>	18.0	1949.190	[S4]
<i>Cephalaspis lyelli</i>	20.0	2928.590	[S5]
<i>Stensiopelta pustulata</i>	21.5	4304.520	[S6]
<i>"Boreaspis" ceratops</i>	12.6	817.420	[S2,S7]
<i>Spatulaspis robusta</i>	8.3	357.909	[S2,S7]

**Table S4. Additional information for the three-dimensional models of the eight selected species of osteostracans, including consulted sources, inferred total lengths and surface areas of the shield. Related to STAR Methods.**

## SUPPLEMENTAL REFERENCES

- S1. Stensiö, E.A. (1927). The Devonian and Downtonian vertebrates of Spitsbergen. 1. Family Cephalaspidae. *Skrifter om Svalbard og Ishavet* 12, 1–391.
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