

**The scaling and allometry of organ size associated with miniaturization in
insects: A case study for Coleoptera and Hymenoptera**

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Table S1. Volumes of organs

Taxon	Stage	Body length, mm	Body volume, nl	Organ volume, nl							
				Skeleton	Musculature	Digestive system	Malpighian tubules	Circulatory system and fat body	Central nervous system	Brain	Reproductive system
<i>Lepisma saccharina</i>	Adult	9.0	9867.5	663.9	1534.0	1326.6	118.7	5021.9	260.5	38.5	941.9
<i>Lepisma saccharina</i>	Adult	8.0	9579.8	—	—	—	—	—	325.9	60.3	—
<i>Liposcelis bostrychophila</i>	Adult	0.9	28.714	1.658	1.881	6.049	0.325	14.341	0.787	0.338	3.673
<i>Liposcelis bostrychophila</i>	Adult	0.9	30.802	—	—	—	—	—	1.296	0.584	—
<i>Liposcelis bostrychophila</i>	Nymph 1 ins	0.33	2.284	0.210	0.300	0.285	0.000	1.119	0.370	0.184	—
<i>Liposcelis bostrychophila</i>	Nymph 1 ins	0.33	2.525	—	—	—	—	—	0.392	0.302	—
<i>Copostigma</i> sp.	Adult	5.0	2289.7	136.7	828.3	307.4	8.7	798.1	63.4	24.3	147.2
<i>Copostigma</i> sp.	Adult	5.0	2286.4	—	—	—	—	—	65.0	26.5	—
<i>Heliothrips haemorrhoidalis</i>	Adult	1.4	40.99	7.18	3.86	6.52	0.42	17.02	1.45	0.58	4.53
<i>Heliothrips haemorrhoidalis</i>	Adult	1.4	39.959	—	—	—	—	—	1.225	0.675	—
<i>Heliothrips haemorrhoidalis</i>	Nymph 1 ins	0.45	3.176	0.232	0.211	0.385	0.036	1.781	0.531	0.238	—
<i>Heliothrips haemorrhoidalis</i>	Nymph 1 ins	0.45	3.090	—	—	—	—	—	0.518	0.259	—
<i>Atheta</i> sp.	Adult	1.5	36.880	5.131	5.503	3.560	0.153	18.531	1.827	0.921	2.175
<i>Ochthebius</i> sp.	Adult	2.0	589.5	69.5	163.9	44.2	6.9	180.4	19.2	8.5	105.4
<i>Aleochara</i> sp.	Adult	8.0	9471.9	990.8	1391.6	952.0	144.6	5494.1	123.9	27.8	374.9
<i>Staphylinus caesareus</i>	Adult	8.0	9471.9	—	—	—	—	—	—	30.0	—
<i>Staphylinus caesareus</i>	Adult	20	65850.3	6865.5	11378.0	8710.0	—	34949.8	876.9	197.9	3070.1
<i>Acrotichis grandicollis</i>	Adult	0.9	82.03	9.26	22.69	7.58	0.38	33.11	4.19	2.12	4.82
<i>Acrotichis grandicollis</i>	Adult	1.0	96.94	—	—	—	—	—	4.460	1.880	—
<i>Acrotichis montandoni</i>	Adult	0.75	47.47	5.08	10.20	2.33	0.21	24.75	2.32	1.23	—
<i>Mikado</i> sp.	Adult	0.45	7.600	0.800	0.660	0.380	0.059	4.284	0.506	0.334	0.934
<i>Mikado</i> sp.	Adult	0.43	6.320	—	—	—	—	—	—	—	0.804
<i>Mikado</i> sp.	Adult	0.45	7.200	—	—	—	—	—	—	0.388	—
<i>Mikado</i> sp.	Larva 1 ins	0.43	0.432	0.038	0.014	0.030	0.003	0.277	0.070	0.024	—
<i>Mikado</i> sp.	Larva 1 ins	0.43	0.441	—	—	—	—	—	0.074	0.022	—
<i>Mikado</i> sp.	Larva 3 ins	0.84	0.863	0.118	0.029	0.083	0.010	0.582	0.040	0.018	—
<i>Nanosella russica</i>	Adult	0.35	2.141	0.387	0.254	0.097	0.015	0.686	0.181	0.090	0.520
<i>Nanosella russica</i>	Adult	0.35	2.648	—	—	—	—	—	0.200	0.094	—
<i>Nanosella</i> sp.	Adult	0.38	6.170	1.090	0.640	0.200	0.022	2.920	0.390	0.250	0.650
<i>Primorskiella anodonta</i>	Adult	0.49	9.240	1.720	1.580	0.800	0.031	3.390	0.580	0.370	0.765
<i>Porophilla mystacea</i>	Adult	0.63	21.130	3.080	4.810	0.990	0.088	8.130	0.940	0.560	2.515
<i>Porophilla mystacea</i>	Adult	0.62	20.450	2.965	5.045	1.023	0.094	6.908	1.207	0.573	2.636
<i>Sericoderus lateralis</i>	Adult	1.0	82.60	9.34	12.03	13.76	1.35	22.84	4.56	1.97	18.72
<i>Sericoderus lateralis</i>	Adult	1.1	86.047	—	—	—	—	—	4.582	1.969	—
<i>Sericoderus lateralis</i>	Adult	1.1	129.406	—	—	—	—	—	—	—	23.924
<i>Sericoderus lateralis</i>	Larva 4 ins	1.7	68.317	8.537	6.886	12.235	1.030	38.639	0.991	0.343	—
<i>Sericoderus lateralis</i>	Larva 1 ins	0.6	5.536	0.449	0.575	1.045	0.057	2.903	0.507	0.196	—
<i>Sericoderus lateralis</i>	Larva 1 ins	0.6	5.495	—	—	—	—	—	0.509	0.199	—
<i>Orthoperus atomus</i>	Adult	0.8	50.284	6.439	10.149	5.261	0.863	22.860	2.189	1.152	2.524
<i>Anaphes flavipes</i>	Adult	0.45	7.486	0.713	1.433	0.366	0.038	3.446	0.744	0.496	0.745
<i>Anaphes flavipes</i>	Adult	0.45	7.658	—	—	—	—	—	0.763	0.376	—
<i>Anaphes flavipes</i>	Adult	0.4	5.383	—	—	—	—	—	0.635	0.379	—
<i>Trichogramma</i> sp.	Adult	0.5	7.994	0.495	1.518	0.354	0.043	3.416	0.803	0.554	1.365
<i>Trichogramma</i> sp.	Adult	0.5	7.830	—	—	—	—	—	0.909	0.607	—
<i>Trichogramma evanescens</i>	Adult	0.4	4.343	—	—	—	—	—	0.518	0.363	0.502
<i>Trichogramma evanescens</i>	Adult	0.4	4.602	—	—	—	—	—	0.515	0.309	—
<i>Anagrus</i> sp.	Adult	0.65	8.512	—	2.079	—	—	—	—	0.742	—
<i>Hemiptarsenus</i> sp.	Adult	3.0	191.61	21.65	32.56	11.45	0.46	73.04	4.54	2.48	47.91
<i>Hemiptarsenus</i> sp.	Adult	3.0	285.06	—	—	—	—	—	11.21	7.47	—
<i>Megaphragma mymaripenne</i>	Adult	0.25	0.992	0.094	0.188	0.062	0.004	0.475	0.082	0.045	0.076
<i>Megaphragma mymaripenne</i>	Adult	0.22	0.804	—	—	—	—	—	0.054	0.037	0.081
<i>Megaphragma mymaripenne</i>	Adult	0.22	0.696	—	—	—	—	—	0.052	0.029	0.060

Table S2. Scaling of organ volume and body volume in adult insects.

Taxon	SMA				OLS				PGLS				MCMCglmm			
	Elevation	Slope	R ²	CI for slope 95%	Elevation	Slope	R ²	CI for slope 95%	Intercept	Slope	R ²	CI for slope 95%	Elevation	Slope	R ²	CI for slope 95%
Skeleton																
Ins.	-0.925	0.975	0.987	0.924 1.028	-0.913	0.979	0.987	0.922 1.037	-1.009	0.987	0.983	0.927 1.047	-0.959	0.968	0.985	0.924 1.017
Col.	-0.836	0.967 *	0.996	0.931 1.004	-0.839	0.965 *	0.998	0.929 1.006	-0.889	0.988	0.982	0.910 1.066	-0.837	0.965	0.995	0.920 1.015
Hym.	-1.110	1.055	0.990	0.789 1.412	-1.105	1.050	0.990	0.739 1.362	-1.051	1.044	0.999	1.028 1.060	-	-	-	-
Par.	-0.909	0.923	0.934	0.139 6.144	-0.844	0.893	0.934	-2.109 3.896	-0.796	0.888	0.952	0.500 1.276	-	-	-	-
Musculature																
Ins.	-0.840	1.038	0.981	0.976 1.105	-0.823	1.029	0.981	0.965 1.093	-0.929	1.057	0.973	0.979 1.135	-0.912	1.050	0.980	0.981 1.124
Col.	-0.842	1.041	0.986	0.967 1.120	-0.829	1.033	0.986	0.957 1.110	-0.900	1.059	0.973	0.956 1.162	-0.855	1.045	0.985	0.958 1.137
Hym.	-0.682	0.974	0.995	0.862 1.101	-0.680	0.972	0.995	0.852 1.091	-0.681	0.966	0.997	0.893 1.039	-	-	-	-
Par.	-1.672	1.367 *	0.998	0.888 2.106	-1.670	1.367 *	0.998	0.757 1.976	-1.661	1.366 *	0.999	1.287 1.445	-	-	-	-
Digestive system																
Ins.	-1.304	1.109 ***	0.980	1.040 1.183	-1.284	1.099 **	0.980	1.027 1.170	-1.108	1.059	0.971	0.976 1.142	-1.125	1.063 *	0.979	0.987 1.133
Col.	-1.339	1.108 **	0.985	1.029 1.194	-1.325	1.101 **	0.985	1.018 1.183	-1.188	1.065	0.969	0.954 1.176	-1.213	1.076	0.984	0.978 1.164
Hym.	-1.286	1.010	0.994	0.815 1.251	-1.284	1.007	0.994	0.789 1.225	-1.264	1.012	0.998	0.933 1.091	-	-	-	-
Par.	-0.618	0.923	0.996	0.473 1.802	-0.615	0.922	0.996	0.258 1.586	-0.626	0.923	0.997	0.837 1.009	-	-	-	-
Malpighian tubules																
Ins.	-2.386	1.111 **	0.960	1.010 1.222	-2.348	1.089 *	0.960	0.983 1.195	-2.215	1.028	0.931	0.895 1.161	-2.256	1.063	0.956	0.960 1.178
Col.	-2.474	1.183 **	0.960	1.038 1.349	-2.436	1.160 **	0.960	1.004 1.316	-2.163	1.055	0.928	0.873 1.237	-2.298	1.131	0.954	0.967 1.287
Hym.	-2.284	0.892	0.981	0.598 1.331	-2.276	0.884	0.981	0.517 1.251	-2.294	0.871	0.990	0.703 1.039	-	-	-	-
Par.	-1.582	0.749 ***	0.999	0.740 0.758	-1.582	0.749 ***	0.999	0.740 0.758	-1.582	0.749 ***	1	0.748 0.750	-	-	-	-
Circulatory system and fat body																
Ins.	-0.393	1.013	0.995	0.981 1.046	-0.389	1.010	0.995	0.978 1.043	-0.397	1.014	0.989	0.966 1.062	-0.386	1.011	0.994	0.975 1.048
Col.	-0.433	1.030	0.993	0.980 1.082	-0.427	1.026	0.993	0.976 1.077	-0.430	1.024	0.988	0.955 1.093	-0.444	1.026	0.993	0.961 1.090
Hym.	-0.310	0.955 **	0.999	0.919 0.992	-0.310	0.955 **	0.999	0.918 0.991	-0.304	0.951 **	0.999	0.934 0.968	-	-	-	-
Par.	-0.239	0.934	0.998	0.602 1.448	-0.238	0.933	0.998	0.511 1.356	-0.245	0.934	0.999	0.880 0.988	-	-	-	-
Central nervous system																
Ins.	-1.020	0.833 ***	0.972	0.783 0.885	-0.999	0.821 ***	0.972	0.770 0.872	-1.000	0.813 ***	0.912	0.696 0.930	-0.978	0.821 ***	0.972	0.765 0.879
Col.	-1.075	0.838 ***	0.982	0.777 0.903	-1.061	0.830 ***	0.982	0.767 0.894	-1.038	0.82 **	0.907	0.665 0.975	-1.044	0.825 ***	0.999	0.748 0.893
Hym.	-0.702	0.665 ***	0.974	0.577 0.768	-0.692	0.657 ***	0.974	0.561 0.752	-0.631	0.564 **	0.999	0.543 0.585	-0.728	0.685 **	0.970	0.450 0.926
Par.	-1.416	0.960	0.995	0.872 1.057	-1.411	0.958	0.995	0.865 1.050	-1.459	0.974	0.997	0.884 1.064	-2.068	1.058	0.993	0.228 4.444
Brain																
Ins.	-1.089	0.697 ***	0.960	0.651 0.746	-1.063	0.683 ***	0.960	0.635 0.731	-1.176	0.706 ***	0.966	0.647 0.765	-1.146	0.714 ***	0.960	0.658 0.772
Col.	-1.137	0.699 ***	0.985	0.658 0.744	-1.128	0.694 ***	0.985	0.651 0.737	-1.158	0.716 ***	0.976	0.650 0.782	-1.131	0.707 ***	0.986	0.645 0.762
Hym.	-0.889	0.662 ***	0.933	0.537 0.816	-0.864	0.640 ***	0.933	0.501 0.779	-0.696	0.480 **	0.975	0.366 0.594	-0.876	0.656 **	0.925	0.434 0.922
Par.	-1.713	0.929	0.993	0.828 1.042	-1.706	0.926	0.993	0.819 1.033	-1.818	0.956	0.998	0.891 1.021	-1.859	0.997	0.991	0.504 1.544
Reproductive system																
Ins.	-0.907	0.961 *	0.973	0.896 1.002	-0.887	0.948 *	0.973	0.881 1.015	-0.679	0.878 **	0.930	0.764 0.992	-0.772	0.918 *	0.969	0.820 1.011
Col.	-0.803	0.907 *	0.966	0.809 1.016	-0.775	0.891 **	0.966	0.788 0.995	-0.624	0.838 *	0.929	0.687 0.989	-0.676	0.876 *	0.958	0.738 1.007
Hym.	-1.077	1.212 **	0.995	1.120 1.312	-1.076	1.209 **	0.995	1.113 1.305	-1.149	1.235 **	0.998	1.171 1.299	-1.088	1.205 **	0.991	1.020 1.367
Par.	-0.697	0.852 *	0.999	0.641 1.132	-0.696	0.852 *	0.999	0.606 1.097	-0.700	0.852 *	0.999	0.820 0.884	-	-	-	-

Ins. – Insects. all; Col. – Coleoptera; Hym. – Hymenoptera; Par. – Paraneoptera.

The following parameters was used to run MCMCglmm and PGLS: lambda – 1; prior – V=1, nu=0.002; number of iterations – 240 000; length of burnin – 40 000; amount of thinning – 100; convergence of the chains were analyzed using the Gelman and Rubin Multiple Sequence Diagnostic, Grafen transformation make the phylogeny ultrametric.

* p-value for slope different from 1. 0.05≤p<0.1; ** 0.01≤p<0.05; *** p<0.01

Table S3. Scaling of relative volume of organs and body volume in adult insects.

Taxon	MA				OLS				PGLS				MCMCglmm			
	Elevation	Slope	R ²	CI for slope 95%	Elevation	Slope	R ²	CI for slope 95%	Intercept	Slope	R ²	CI for slope 95%	Elevation	Slope	R ²	CI for slope 95%
Skeleton																
Ins.	-0.903	-0.032	0.073	-0.085 0.021	-0.904	-0.031	0.073	-0.084 0.020	-1.009	-0.012	0.009	-0.072 0.048	-0.959	-0.031	0.045	-0.081 0.015
Col.	-0.833	-0.034	0.266	-0.071 0.001	-0.833	-0.034 *	0.266	-0.070 0.001	-0.889	-0.011	0.007	-0.089 0.067	-0.835	-0.035	0.206	-0.083 0.011
Hym.	-1.105	0.051 *	0.195	-0.296 0.411	-1.105	0.050	0.195	-0.261 0.362	-1.051	0.044	0.965	0.028 0.060	-	-	-	-
Par.	-0.830	-0.113	0.169	-	-0.843	-0.106	0.169	-3.109 2.896	-0.796	-0.111	0.242	-0.499 0.277	-	-	-	-
Musculature																
Ins.	-0.824	0.029	0.040	0.029 0.095	-0.823	0.029	0.040	-0.034 0.093	-0.929	0.057	0.099	-0.021 0.135	-0.911	0.049	0.044	-0.015 0.123
Col.	-0.830	0.034	0.072	-0.043 0.112	-0.829	0.033	0.072	-0.042 0.110	-0.900	0.059	0.104	-0.044 0.162	-0.855	0.044	0.084	-0.048 0.129
Hym.	-0.679	-0.027	0.153	-0.150 0.093	-0.680	-0.027	0.153	-0.147 0.091	-0.681	-0.033	0.289	-0.106 0.040	-	-	-	-
Par.	-1.672	0.367 *	0.983	-	-1.670	0.367 *	0.983	-0.242 0.976	-1.661	0.366 *	0.988	0.287 0.445	-	-	-	-
Digestive system																
Ins.	-1.289	0.101	0.295	0.028 0.175	-1.284	0.099***	0.295	0.027 0.170	-1.108	0.059	0.098	-0.024 0.142	-1.131	0.064 *	0.268	-0.005 0.139
Col.	-1.328	0.102	0.371	0.018 0.188	-1.325	0.101 **	0.371	0.018 0.183	-1.188	0.065	0.107	-0.046 0.176	-1.218	0.078 *	0.324	-0.016 0.176
Hym.	-1.28	0.007	0.011	-0.222 0.238	-1.284	0.007	0.011	-0.210 0.225	-1.264	0.012	0.083	-0.067 0.091	-	-	-	-
Par.	-0.615	-0.077	0.688	-	-0.615	-0.077	0.688	-0.741 0.586	-0.626	-0.076	0.753	-0.162 0.010	-	-	-	-
Malpighian tubules																
Ins.	-2.356	0.094 ***	0.141	-0.017 0.208	-2.348	0.089 *	0.141	-0.016 0.195	-2.215	0.028	0.010	-0.105 0.161	-2.260	0.063	0.123	-0.052 0.176
Col.	-2.637	0.284 **	0.318	0.168 0.479	-2.436	0.160 **	0.318	0.004 0.316	-2.163	0.055	0.034	-0.127 0.237	-2.300	0.133 **	0.273	-0.019 0.301
Hym.	-2.223	-0.167	0.479	-0.769 0.036	-2.276	-0.115	0.479	-0.482 0.251	-2.294	-0.128	0.693	-0.296 0.040	-	-	-	-
Par.	-1.582	-0.250 ***	0.999	-0.259 -0.241	-1.582	-0.250 ***	0.999	-0.259 -0.241	-1.582	-0.25	1	-0.251 -0.249	-	-	-	-
Circulatory system and fat body																
Ins.	-0.389	0.010	0.022	-0.021 0.043	-0.389	0.010	0.022	-0.021 0.043	-0.397	0.014	0.019	-0.034 0.062	-0.390	0.012	0.018	-0.021 0.049
Col.	-0.428	0.027	0.100	-0.024 0.078	-0.427	0.026	0.100	-0.023 0.077	-0.430	0.024	0.046	-0.045 0.093	-0.446	0.026	0.081	-0.033 0.095
Hym.	-0.310	-0.044 **	0.839	-0.081 -0.008	-0.310	-0.044 **	0.839	-0.081 -0.008	-0.304	-0.048 **	0.939	-0.065 -0.031	-	-	-	-
Par.	-0.238	-0.066	0.797	-0.637 0.464	-0.238	-0.066	0.797	-0.488 0.356	-0.245	-0.065	0.846	-0.119 -0.011	-	-	-	-
Central nervous system																
Ins.	-0.993	-0.181 ***	0.624	-0.234 -0.130	-0.999	-0.178 ***	0.624	-0.229 -0.127	-1.000	-0.186 ***	0.352	-0.303 -0.069	-0.975	-0.178 ***	0.636	-0.233 -0.120
Col.	-1.057	-0.171 ***	0.701	-0.236 -0.107	-1.061	-0.169 ***	0.701	-0.232 -0.105	-1.038	-0.179 **	0.320	-0.334 -0.024	-1.044	-0.175 ***	0.687	-0.249 -0.103
Hym.	-0.688	-0.346 ***	0.911	-0.4465 -0.252	-0.692	-0.342 ***	0.911	-0.438 -0.247	-0.631	-0.435 **	0.999	-0.456 -0.414	-0.725	-0.316 **	0.900	-0.510 -0.065
Par.	-1.410	-0.041	0.281	-0.136 0.051	-1.411	-0.041	0.281	-0.134 0.050	-1.459	-0.025	0.236	-0.115 0.065	-1.841	0.157	0.238	-0.843 1.083
Brain																
Ins.	-1.053	-0.322 ***	0.838	-0.371 -0.274	-1.063	-0.316 ***	0.838	-0.364 -0.268	-1.176	-0.293 ***	0.833	-0.352 -0.234	-1.141	-0.286 ***	0.831	-0.344 -0.230
Col.	-1.124	-0.307 ***	0.928	-0.351 -0.264	-1.128	-0.305 ***	0.928	-0.348 -0.262	-1.158	-0.284 ***	0.865	-0.350 -0.217	-1.133	-0.292 ***	0.929	-0.352 -0.233
Hym.	-0.853	-0.369 ***	0.815	-0.521 -0.230	-0.864	-0.359 ***	0.815	-0.498 -0.220	-0.696	-0.519 **	0.975	-0.633 -0.405	-0.875	-0.345 **	0.797	-0.576 -0.123
Par.	-1.705	-0.073	0.477	-0.183 0.033	-1.706	-0.073	0.477	-0.180 0.033	-1.818	-0.043	0.629	-0.108 0.022	-1.909	-0.018	0.422	-0.576 0.394
Reproductive system																
Ins.	-0.885	-0.052	0.098	-0.121 0.016	-0.887	-0.051	0.098	-0.118 0.015	-0.679	-0.121 *	0.203	-0.235 -0.007	-0.773	-0.081 *	0.240	-0.175 0.018
Col.	-0.770	-0.111 **	0.300	-0.220 -0.004	-0.775	-0.108 ***	0.300	-0.211 -0.004	-0.624	-0.161*	0.328	-0.312 -0.010	-0.676	-0.124 **	0.344	-0.262 0.002
Hym.	-1.077	0.210 ***	0.863	0.115 0.310	-1.076	0.209 ***	0.863	0.113 0.305	-1.149	0.235**	0.963	0.171 0.299	-1.093	0.207 **	0.763	0.027 0.369
Par.	-0.696	-0.147*	0.983	-0.419 0.104	-0.696	-0.147 ***	0.983	-0.393 0.097	-0.700	-0.147*	0.988	-0.179 -0.115	-	-	-	-

Ins. – Insects. all; Col. – Coleoptera; Hym. – Hymenoptera; Par. – Paraneoptera.

The following parameters was used to run MCMCglmm and PGLS: lambda – 1; prior – V=1, nu=0.002; number of iterations – 240 000; length of burnin – 40 000; amount of thinning – 100; convergence of the chains were analyzed using the Gelman and Rubin Multiple Sequence Diagnostic, Grafen transformation make the phylogeny ultrametric.

* p-value for slope different from 1. 0.05≤p<0.1; ** 0.01≤p<0.05; *** p<0.01