

**Table 1.** Summary of individuals of speckled cockroach (n = 15) that showed discontinuous gas exchange (DGE) used for calculation of mean values in main text (Table 1) of the measured physiological variables. IB = Interburst; B = burst; TWL = total water loss; RWL = respiratory water loss; CWL = cuticular water loss; CP ( $\mu\text{g h}^{-1} \text{cm}^{-2} \text{hPa}^{-1}$ ) = cuticular permeability.

mg	VCO <sub>2</sub>			VCO <sub>2</sub>		Durations			Durations		VH <sub>2</sub> O			VH <sub>2</sub> O		TWL Components				
	$\mu\text{L g}^{-1} \text{h}^{-1}$			% of Total		seconds			% of Total		$\mu\text{g g}^{-1} \text{h}^{-1}$			% of Total		$\mu\text{g g}^{-1} \text{h}^{-1}$				
	IB	B	total	IB	B	IB	B	overall	IB	B	IB	B	TWL	IB	B	RWL	CWL	RWL	CWL	CP
500	39.2	442	158	17.2	85.6	612	270	882	69.4	30.6	1017	1422	1141	61.8	38.2	124	1017	10.9	89.1	5.17
970	43.5	327	153	19.5	68	215	100	315	68.3	31.7	858	1131	944	62	38	86.9	858	9.2	90.8	4.99
610	27.1	213	158	5.15	94.8	34.3	80	114	30	70	553	591	580	28.6	71.4	26.5	553	4.57	95.4	2.58
610	84.7	430	249	19.2	75.4	178	138	315	56.3	43.7	1198	1349	1264	53.4	46.6	65.9	1198	5.21	94.8	5.72
510	58.4	324	177	18.7	79	186	142	328	56.7	43.3	1266	1550	1389	51.7	48.3	123	1266	8.84	91.2	5.75
630	61.4	197	172	7.3	91	90	350	440	20.5	79.5	760	897	869	17.9	82.1	108	760	12.5	87.5	3.9
780	48.6	304	240	5.07	94.9	60	180	240	25	75	1446	1555	1528	23.7	76.3	82.1	1446	5.38	94.6	7.1
560	25.3	406	200	5.41	116	167	222	388	42.9	57.1	546	817	701	33.5	66.5	154	546	22	78	3
770	21	354	245	2.77	98	166	348	514	32.3	67.7	434	595	543	25.8	74.2	109	434	20	80	2.85
800	30.3	601	210	10.1	85.3	300	128	428	70.1	29.9	939	1381	1071	61.5	38.5	132	939	12.3	87.7	5.44
600	22.8	392	197	6.08	94.4	140	127	267	52.5	47.5	579	819	693	43.9	56.1	114	579	16.4	83.6	3.07
600	40.5	334	205	8.61	91.7	127	163	290	43.7	56.3	675	828	762	38.7	61.3	86.3	675	11.3	88.7	3.42
500	34.2	334	222	5.82	93.5	150	247	397	37.8	62.2	710	826	782	34.3	65.7	71.9	710	9.19	90.8	3.35
810	61.2	272	165	17.3	88	204	234	438	46.6	53.4	1478	1659	1575	43.7	56.3	96.9	1478	6.15	93.8	7.81
880	33.8	194	179	1.79	98.3	28	268	296	9.46	90.5	280	307	304	8.7	91.3	24.4	280	8.03	92	1.54

**Table 2.** Summary of individuals of speckled cockroach (n = 8) and of beetles (n = 8) that showed continuous gas exchange (CGE) used for calculation of mean values in main text (Table 1) of the measured physiological variables. TWL = total water loss; RWL = respiratory water loss; CWL = cuticular water loss; CP ( $\mu\text{g h}^{-1} \text{cm}^{-2} \text{hPa}^{-1}$ ) = cuticular permeability.

Cockroach Individuals Showing CGE.								Beetle Individuals Showing CGE							
Mass	VCO2	VH2O	TWL Components					Mass	VCO2	VH2O	TWL Components				
mg	$\mu\text{L g}^{-1} \text{h}^{-1}$	$\mu\text{g g}^{-1} \text{h}^{-1}$	$\mu\text{g g}^{-1} \text{h}^{-1}$					mg	$\mu\text{L g}^{-1} \text{h}^{-1}$	$\mu\text{g g}^{-1} \text{h}^{-1}$	$\mu\text{g g}^{-1} \text{h}^{-1}$				
	Total	TWL	RWL	CWL	RWL	CWL	CP		Total	TWL	RWL	CWL	RWL	CWL	CP
990	475	708	85.6	612	270	882	3.86	520	278	2739	461	2278	16.8	83.2	12.1
840	175	446	68	215	100	315	2.41	580	255	2179	389	1790	17.8	82.2	10.3
1030	220	415	94.8	34.3	80	114	2.51	630	197	1493	230	1264	15.4	84.6	7.07
640	268	607	75.4	178	138	315	2.79	590	308	1105	220	885	19.9	80.1	5.42
750	326	609	79	186	142	328	2.77	610	469	789	139	650	17.6	82.4	3.96
870	236	3537	91	90	350	440	17.4	600	373	3073	595	2478	19.4	80.6	15.1
790	238	2024	94.9	60	180	240	9.41	490	246	826	143	683	17.3	82.7	3.46
550	161	561	116	167	222	388	2.53	620	327	1919	298	1621	15.5	84.5	9.1

**Table 3.** Body mass and metabolic rate (both measured and  $Q_{10}$  corrected to 23°C using a  $Q_{10}$  of 2) of cockroach species showing CGE and DGE from literature (8) and *Nauphoeta cinerea* from this study used for regression comparison of metabolic cost between CGE and DGE species shown in Figure 3a (columns shaded grey were used for regression relationships).

Family	Species	Mass (M) g	Pattern	Metabolic Rate (MR) mL h <sup>-1</sup>	Measurement Temperature °C	MR ( $Q_{10}$ ) at 23°C mL h <sup>-1</sup>	Log M	Log MR	References
	<i>Macropanesthia rhinoceros</i>	26.5	DGE	0.887	20	1.09	1.42	0.0382	[1]
	<i>Blaberus giganteus</i>	4.33	DGE	0.589	26.6	0.459	0.636	-0.338	[2]
	<i>Blaberid</i> sp	2.54	DGE	0.091	22	0.0975	0.405	-1.01	[3]
	<i>Aptera fusca</i>	2.29	CGE	0.12	15	0.209	0.359	-0.680	[4]
		2.23	DGE	0.09	15	0.157	0.348	-0.805	[4]
Blaberidae		0.808	CGE	0.212	23	0.212	-0.0929	-0.674	This study
	<i>Nauphoeta cinerea</i>	0.675	DGE	0.132	23	0.132	-0.171	-0.881	This study
		0.56	DGE	0.118	25	0.103	-0.252	-0.988	[5]
		0.547	CGE	0.170	25	0.148	-0.262	-0.829	[6]
		0.394	DGE	0.0336	21	0.0386	-0.405	-1.41	[7]
		0.389	CGE	0.0362	20	0.0445	-0.410	-1.35	[8]
	<i>Perisphaeria</i> sp.	0.386	CGE	0.0483	21	0.0555	-0.413	-1.26	[7]
		0.315	DGE	0.091	20	0.0255	-0.502	-1.59	[8]
Blattidae	<i>Periplaneta americana</i>	1.1	DGE	0.3	25	0.261	0.0414	-0.583	[9]
Blatellidae	<i>Blatella germanica</i>	0.054	DGE	0.021	10	0.0517	-1.27	-1.29	[10]
		0.049	DGE	0.024	10	0.0591	-1.31	-1.23	[10]

**Table 4.** Body mass and metabolic rate (both measured and  $Q_{10}$  corrected to 23°C using a  $Q_{10}$  of 2) of tenebrionid species showing CGE and DGE from literature (23) and *Zophobas morio* from this study used for regression comparison of metabolic cost between CGE and DGE species shown in Figure 3b (columns shaded grey were used for regression relationship).

Species	Mass (M) g	Pattern	Metabolic Rate (MR) ml h <sup>-1</sup>	Measurement Temperature °C	MR ( $Q_{10}$ ) at 23°C ml h <sup>-1</sup>	Log M	Log MR	References
<i>Pimelia grandis</i> Klug	2.10	CGE	0.535	25	0.466	0.322	-0.332	[11]
<i>Eloedes obscura</i>	1.26	CGE	0.27	22	0.289	0.0997	-0.539	[12]
<i>Trachyderma hispida</i> (Forsk.)	1.03	CGE	0.292	25	0.254	0.0141	-0.595	[11]
<i>Helea waitei</i> Lea	0.865	CGE	0.192	25	0.167	-0.0630	-0.777	[13]
<i>Trachyderma philistina</i> Riche & Sauley	0.859	CGE	0.24	25	0.209	-0.0660	-0.680	[11]
<i>Zophobas morio</i>	0.58	CGE	0.178	23	0.178	-0.237	-0.750	This study
<i>Helea</i> sp.	0.481	CGE	0.102	25	0.0888	-0.318	-1.052	[13]
<i>Akis goryi</i> Solier	0.478	CGE	0.092	25	0.0801	-0.321	-1.10	[11]
<i>Scaurus puncticolis</i> Solier	0.282	CGE	0.037	25	0.032	-0.550	-1.49	[11]
<i>Pterohelaeus</i> sp. Brême	0.245	CGE	0.069	25	0.0601	-0.611	-1.22	[14]
<i>Brises blairi</i> Carter	0.162	CGE	0.064	25	0.0557	-0.790	-1.25	[13]
<i>Psammodes striatus</i>	2.8	DGE	0.364	20	0.448	0.447	-0.349	[15]
<i>Epiphysa arenicola</i>	1.24	DGE	0.0951	30	0.0585	0.0924	-1.23	[16]
<i>Onymacris plana</i>	0.767	DGE	0.188	30	0.115	-0.115	-0.937	[16]
<i>O. unguicularis</i>	0.585	DGE	0.127	30	0.0779	-0.233	-1.11	[16]
<i>O. rugatipennis</i> a.	0.573	DGE	0.117	30	0.0722	-0.242	-1.14	[16]
<i>O. laeviceps</i>	0.525	DGE	0.0867	30	0.0534	-0.280	-1.27	[16]
<i>Physadesmia globosa</i>	0.516	DGE	0.122	30	0.0748	-0.287	-1.13	[16]
<i>Pimelia canascens</i>	0.312	DGE	0.036	25	0.0313	-0.506	-1.50	[11]
<i>Stenocara gracilipes</i>	0.268	DGE	0.0965	30	0.0594	-0.572	-1.23	[16]
<i>Zophosis complanata</i>	0.112	DGE	0.02	25	0.0174	-0.951	-1.76	[11]
<i>Zophosis orbicularis</i>	0.103	DGE	0.0246	30	0.0151	-0.987	-1.82	[16]
<i>Z. punctata</i>	0.07	DGE	0.014	25	0.0122	-1.15	-1.91	[11]
<i>Cardiosis fairmarei</i>	0.032	DGE	0.006	30	0.00369	-1.49	-2.43	[16]

**Table 5.** Data for 30 insect species from Woods and Smith (2010) for the regression relationship of respiratory water cost of gas exchange, and the two species from our study were superimposed to the regression relationship (given at the end of the table); 95% confidence and prediction intervals were calculated for the overall regression (Figure 4b). Shaded columns were used for regression relationship).

Species	Mass g	Gas Uptake Rate (X)	Water Loss Rate (Y)	Log X	Log Y	Predict Y	Confidence Interval		Prediction Interval		Pattern	References
		Mol O <sub>2</sub> Day <sup>-1</sup>	Mol H <sub>2</sub> O Day <sup>-1</sup>				Min	Max	Min	Max		
<i>Perisphaeria sp</i>	0.45	6.10E-05	1.54E-04	-4.21	-3.81	-3.76	-3.93	-3.59	-4.59	-2.93	CGE	[7]
<i>Aphodius fossor</i>	0.121	2.68E-05	8.85E-05	-4.57	-4.05	-4.04	-4.19	-3.89	-4.87	-3.22	DGE	[17]
<i>Scarabaeus garipepinus</i>	1.13	3.98E-05	5.44E-04	-4.40	-3.26	-3.91	-4.06	-3.75	-4.74	-3.08	DGE	[18]
<i>Scarabaeus striatus</i>	0.753	3.45E-05	3.56E-04	-4.46	-3.45	-3.96	-4.11	-3.80	-4.78	-3.13	DGE	[18]
<i>Scarabaeus galenus</i>	1.68	1.31E-04	5.81E-04	-3.88	-3.24	-3.50	-3.70	-3.29	-4.34	-2.66	DGE	[18]
<i>Scarabaeus rusticus</i>	1.06	9.70E-05	7.83E-04	-4.01	-3.11	-3.60	-3.79	-3.41	-4.44	-2.77	DGE	[18]
<i>Scarabaeus westwoodi</i>	1.76	1.81E-04	9.53E-04	-3.74	-3.02	-3.39	-3.61	-3.16	-4.23	-2.54	DGE	[18]
<i>Circellium bacchus</i>	7.19	1.76E-04	5.55E-04	-3.75	-3.26	-3.40	-3.61	-3.18	-4.24	-2.55	DGE	[19]
<i>Eleodes obscura</i>	1.28	3.48E-04	6.57E-04	-3.46	-3.18	-3.16	-3.42	-2.90	-4.01	-2.31	CGE	[12]
<i>Omorgus radula</i>	0.207	1.88E-05	1.19E-04	-4.73	-3.93	-4.17	-4.31	-4.0	-4.99	-3.34	DGE	[20]
<i>Blattella germanica</i>	0.0488	2.48E-05	2.67E-06	-4.61	-5.57	-4.07	-4.22	-3.92	-4.90	-3.24	DGE	[10]
<i>Drosophila melanogaster</i>	0.001	1.98E-06	1.39E-05	-5.70	-4.86	-4.94	-5.16	-4.72	-5.78	-4.10	CGE	[21]
<i>Camponotus vicinus</i>	0.0352	1.12E-05	2.87E-05	-4.95	-4.54	-4.34	-4.50	-4.19	-5.17	-3.51	DGE	[22]
<i>Cataglyphis bicolor</i>	0.0245	4.79E-06	2.27E-05	-5.32	-4.64	-4.64	-4.82	-4.46	-5.47	-3.80	DGE	[22]
<i>Crematogaster californica</i>	0.00136	3.80E-06	1.48E-05	-5.42	-4.83	-4.72	-4.91	-4.56	-5.55	-3.88	CGE	[23]
<i>Dorymyrmex insanus</i>	0.000579	2.24E-06	1.11E-05	-5.65	-4.96	-4.90	-5.11	-4.68	-5.74	-4.06	CGE	[23]
<i>Forelius mccooki</i>	0.00027	2.59E-07	1.55E-06	-6.59	-5.81	-5.64	-5.99	-5.29	-6.52	-4.75	CGE	[21]
<i>Linepithema humile</i>	0.000424	2.20E-06	2.38E-05	-5.66	-4.62	-4.90	-5.12	-4.69	-5.75	-4.06	CGE	[23]
<i>Pogonomyrmex rugosus</i>	0.0233	6.08E-06	2.43E-05	-5.22	-4.61	-4.55	-4.72	-4.38	-5.38	-3.72	DGE	[24]
<i>Pogonomyrmex californicus</i>	0.00676	1.69E-06	8.02E-06	-5.77	-5.10	-4.99	-5.23	-4.76	-5.84	-4.15	DGE	[21]
<i>Pogonomyrmex occidentalis</i>	0.00796	2.43E-06	1.96E-05	-5.61	-4.71	-4.87	-5.08	-4.66	-5.71	-4.03	DGE	[25]
<i>Pogonomyrmex barbatus</i>	0.0147	4.71E-06	1.86E-05	-5.33	-4.73	-4.64	-4.82	-4.46	-5.47	-3.81	CGE	[26]
<i>Solenopsis xyloni</i>	0.000431	2.10E-06	1.23E-05	-5.68	-4.91	-4.92	-5.14	-4.70	-5.76	-4.08	CGE	[23]
<i>Incisitermes minor</i>	0.0106	6.13E-06	2.95E-05	-5.21	-4.53	-4.55	-4.72	-4.38	-5.38	-3.72	Cyclic	[27]
<i>Reticulitermes flavipes</i>	0.00496	6.80E-06	1.59E-05	-5.17	-4.80	-4.51	-4.68	-4.35	-5.35	-3.68	Cyclic	[28]
<i>Karoophasma biedouwensis</i>	0.104	2.28E-05	2.57E-04	-4.64	-3.59	-4.10	-4.25	-3.95	-4.93	-3.27	Cyclic	[29]
<i>Melanoplus sanguinipes</i>	0.25	8.07E-05	2.24E-04	-4.09	-3.65	-3.66	-3.85	-3.48	-4.50	-2.83	CGE	[30]
<i>Romalea guttata</i>	2.92	7.88E-04	7.99E-04	-3.10	-3.10	-2.88	-3.19	-2.57	-3.75	-2.01	DGE	[31]

Species	Mass g	Gas Uptake Rate (X)	Water Loss Rate (Y)	Log X	Log Y	Predict Y	Confidence Interval		Prediction Interval		Pattern	References
		Mol O <sub>2</sub> Day <sup>-1</sup>	Mol H <sub>2</sub> O Day <sup>-1</sup>				Min	Max	Min	Max		
<i>Romalea guttata</i>	2.87	5.13E-04	3.6E-04	-3.29	-3.44	-3.03	-3.31	-2.74	-3.89	-2.17	Cyclic	[32]
<i>Taeniopoda eques</i>	2.04	4.69E-04	3.33E-04	-3.33	-3.48	-3.06	-3.34	-2.78	-3.92	-2.20	Cyclic	[32]
<i>Nauphoeta cinerea</i>	0.675	1.66E-04	8.43E-05	-3.78	-4.07						DGE	This study
	0.808	2.67E-04	2.04E-04	-3.57	-3.69						CGE	This study
<i>Zophobas morio</i>	0.58	2.24E-04	2.39E-04	-3.65	-3.62						CGE	This study

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