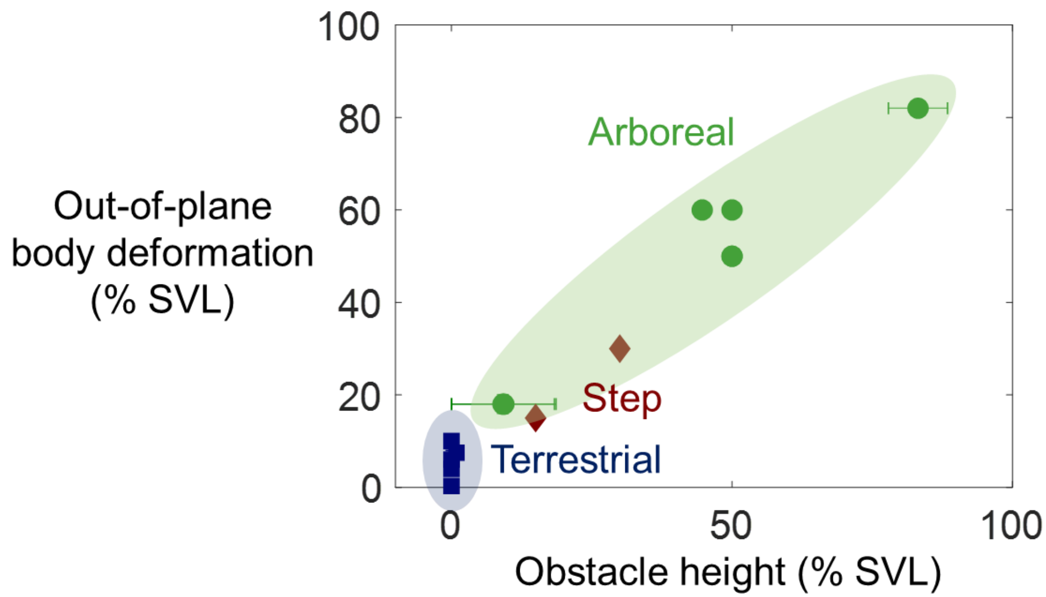
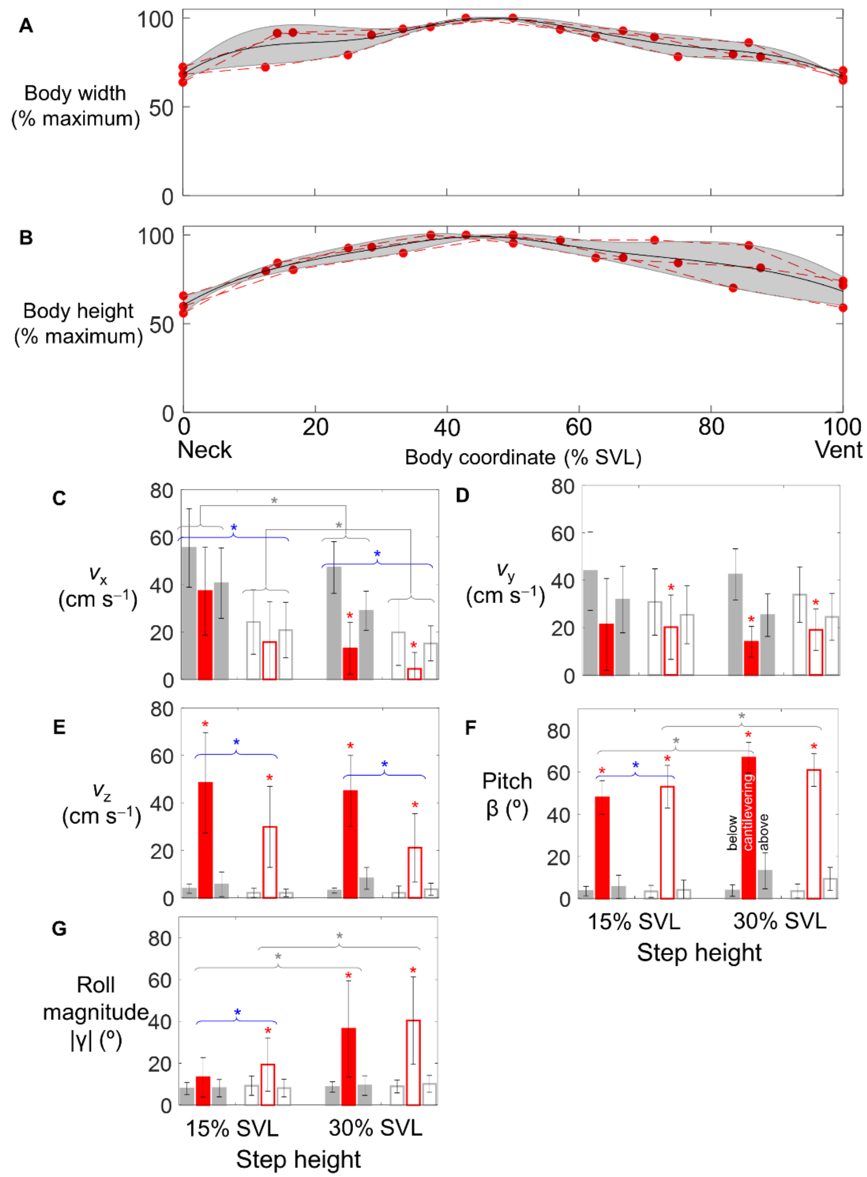


Figure S1. Maximal out-of-plane body deformation as a function of obstacle height comparing our study (red diamonds) with previous studies of arboreal (green circles) and terrestrial (blue squares) snake locomotion (see Table S1).

Journal of Experimental Biology • Supplementary information



Journal of Experimental Biology • Supplementary information

Figure S2. Body width (A) and height (B) along the body. Red markers and dotted lines show measurement points for each individual. Black curves and shaded area show mean ± 1 s.d. Because we could not measure at the exact same body coordinates for each snake, we interpolated measurements along the body. Forward (C), lateral (D), and vertical (E) speeds as a function of step height. Body pitch β (F) and roll magnitude $|\gamma|$ (considering lateral symmetry) (G) as a function of step height. Filled and open bars are for high and low friction treatments, respectively. For each treatment, two gray bars are for body section below (left) and above (right) step, and red bar in between is for cantilevering body section. Error bars show ± 1 s.d. Brackets and/or asterisks represent statistically significant differences between body sections (black), between step height treatments (gray), and between surface friction treatments (blue) ($P < 0.05$, ANOVA, Table S3). Connected brackets represent a significant difference across treatments for all body sections ($P < 0.05$, ANOVA, Table S3).

Table S1. Maximal out-of-plane movement in previous studies of snake locomotion. Starred (*) studies observed substantial out-of-plane body deformation (> 10% snout-vent length). Many other early studies investigated snake movement on flat surfaces but no out-of-plane data were available.

Study	Terrain	Species	SVL (cm)	Obstacle height (cm)	Maximal out-of-plane movement	
					(cm)	(% SVL)
(Marvi and Hu, 2012)	Narrow channel	Corn snake (*Elaphe guttata*)	61 ± 4	0	≈ 0.2	0.30 ± 0.04
(Marvi et al., 2014)	Sandy slope	Sidewinder rattlesnake (*Crotalus cerastes*)	48 ± 6	0	3	6 ± 2
(Jafari et al., 2014)	Air gliding	Paradise tree snake (*Chrysopelea paradise*)	60.3, 74.0	N.A.	6, 7	10, 10
(Jayne and Riley, 2007)	Tree branches	Brown tree snake (*Boiga irregularis*)	43-188	0	2.2-6.4	3-5
(Byrnes and Jayne, 2010)	Tree branches	Boa constrictor (*Boa constrictor*)	66-70	0.3-0.9	~5	7-8
*(Jayne and Herrmann, 2011)	Tree branches	Boa constrictor (*Boa constrictor*)	60.0 ± 0.6	0.2-10.8	10.8	18 ± 2
		Corn snake (*Pantherophis guttatus*)	59.0 ± 0.6	0.2-10.8	10.8	18 ± 2
*(Byrnes and Jayne, 2012)	Tree branches	Brown tree snake (*Boiga irregularis*)	90-102	74-84	74-84	82
*(Hoefer and Jayne, 2013)	Tree branches	Boa constrictor (*Boa constrictor*)	84	42	42	50
		Corn snake (*Pantherophis guttatus*)	68	34	34	50
		Brown tree snake (*Boiga irregularis*)	84	42	50	60
		Brown tree snake (*Boiga irregularis*)	68	34	41	60
Our study	Step	Kingsnake (*Lampropeltis Mexicana*)	34.6 ± 0.4	5-10.5	10.5	30

Journal of Experimental Biology • Supplementary information

Table S2. Results from ANOVAs testing the effects of step height and surface friction on traversal performance. *F* ratios and *P* values are shown as *F*(*P*). *N* = 3 individuals and *n* = 120 trials in total (10 trials for each individual each treatment). Individual is set as a random, crossed factor to account for individual variation. Results for the random individual factor are not shown for simplicity. See **Statistics** in **MATERIALS AND METHODS** for detail.

Effect	Degree of freedom	Dependent variables						
		Traversal time	Traversal speed v_{CoM}	Velocity intermittency	Cantilever length l	Tortuosity τ	Head lift-off distance	Body-lift-off distance
Height	1, 2	12.6 (< 0.001)	5.54 (0.1428)	42.0 (0.023)	198.1 (0.005)	6.9 (0.119)	1.03 (0.312)	4.54 (0.0353)
Friction	1, 2	33.5 (< 0.001)	18696.4 (< 0.001)	42.5 (< 0.001)	2.8 (0.234)	12.7 (0.0704)	106.8 (< 0.001)	35.6 (< 0.001)
Height × Friction	1, 2	0.036 (0.85)	1.9 (0.298)	13.1 (0.643)	5.74 (0.139)	6.9 (0.1199)	3.56 (0.0620)	5.3 (0.0232)

Journal of Experimental Biology • Supplementary information

Table S3. Results from ANOVAs testing the effects of step height, surface friction, and body section (below step, cantilevering, and above step) on traversal kinematics. *F* ratios and *P* values are shown as *F*(*P*). *N* = 3 individuals and *n* = 120 trials in total (10 trials for each individual each treatment). Individual is set as a random, crossed factor to account for individual variation. Results for the random individual factor are not shown for simplicity. For pitch and roll stability margins, stage of traversal is used as a fixed effect; for the remaining measurements, body section is used as a fixed effect; both were indicated by S in the effect column. See **Statistics** in **MATERIALS AND METHODS** for detail.

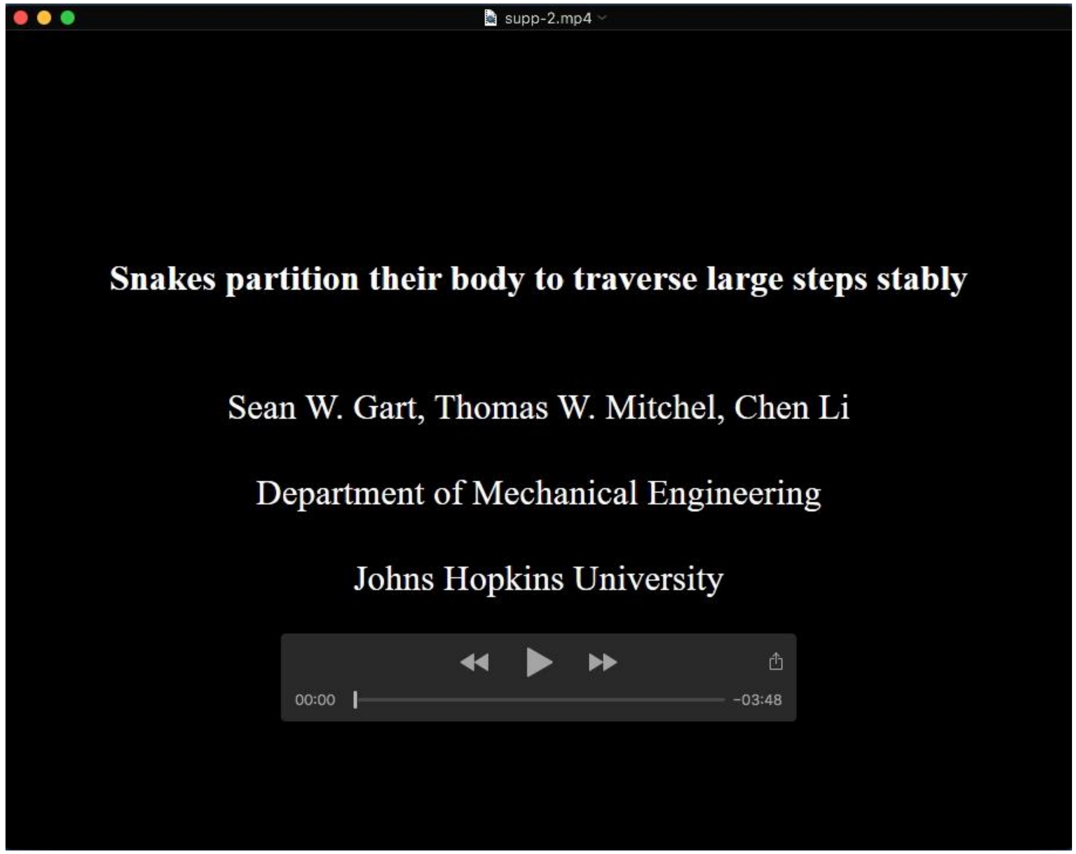
Effect	Degree of freedom	Dependent variables									
		In-plane length	Local curvature κ	Slip angle φ	Forward speed v_x	Lateral speed v_y	Vertical speed v_z	Pitch β	Roll magnitude |γ|	Pitch stability margin	Roll stability margin
Height (H)	1, 2	1.0 (0.43)	39.6 (0.024)	47.0 (0.021)	9.6 (0.091)	0.46 (0.57)	4.5 (0.17)	277.3 (0.004)	33.4 (0.029)	2.0 (0.2954)	6.0 (0.13)
Friction (F)	1, 2	110.3 (0.008)	14.3 (0.063)	156.1 (0.006)	341.7 (0.0029)	43.2 (0.022)	2318.5 (< 0.001)	1.2 (0.39)	1.0 (0.41)	19.0 (0.048)	32.8 (0.029)
Section/Stage (S)	2, 4	51.1 (0.001)	200.7 (< 0.001)	1.3 (0.36)	155.6 (< 0.001)	177.3 (< 0.001)	24.4 (0.006)	407.5 (< 0.001)	19.5 (0.009)	13.8 (0.0157)	16.0 (0.0119)
H × F	1, 2	22.1 (0.041)	2.5 (0.26)	38.9 (0.024)	9.1 (0.091)	7.9 (0.11)	0.84 (0.46)	41.8 (0.023)	0.53 (0.54)	12.1 (0.073)	39.1 (0.022)
F × S	2, 4	70.0 (< 0.001)	0.122 (0.89)	1.1 (0.36)	8.8 (0.034)	19.0 (0.009)	791.7 (< 0.001)	1.4 (0.34)	1.0 (0.54)	1.2 (0.38)	21.5 (0.004)
H × S	2, 4	10.5 (0.025)	69.7 (< 0.001)	7.5 (0.044)	11.8 (0.021)	16.7 (0.011)	17.6 (0.010)	98.3 (< 0.001)	16.5 (0.011)	79.1 (< 0.001)	3.6 (0.12)
H × F × S	2, 4	9.5 (0.030)	9.0 (0.033)	1.2 (0.40)	1.2 (0.38)	0.103 (0.905)	1.1 (0.42)	20.1 (0.008)	5.1 (0.078)	7.1 (0.043)	0.15 (0.86)

Journal of Experimental Biology • Supplementary information

Table S4. Results from ANOVAs testing the effects of step height, surface friction, and body section (below and above step only, no cantilevering) on traversal kinematics. *F* ratios and *P* values are shown as *F*(*P*). $N = 3$ individuals and $n = 120$ trials in total (10 trials for each individual each treatment). Individual is set as a random, crossed factor to account for individual variation. Results for the random individual factor are not shown for simplicity. See **Statistics** in **MATERIALS AND METHODS** for detail.

Effect	Degree of freedom	Dependent variables			
		Lateral oscillation amplitude *A*	Lateral oscillation frequency *f*	Lateral oscillation wavelength λ	Lateral oscillation wavenumber σ
Height (H)	1, 2	167.5 (0.005)	0.01 (0.95)	11.2 (0.078)	5.8 (0.137)
Friction (F)	1, 2	5.0 (0.16)	10.7 (0.082)	24.8 (0.034)	13.3 (0.067)
Section (S)	1, 2	1.9 (0.30)	0.31 (0.63)	47.3 (0.020)	8.9 (0.096)
H × F	1, 2	0.17 (0.72)	10.1 (0.084)	0.23 (0.68)	1.7 (0.32)
F × S	1, 2	0.06 (0.95)	1.6 (0.34)	0.17 (0.722)	0.23 (0.68)
H × S	1, 2	2.3 (0.27)	0.77 (0.48)	1.1 (0.40)	1.6 (0.33)
H × F × S	1, 2	0.25 (0.67)	0.46 (0.57)	1.4 (0.35)	0.16 (0.73)

Journal of Experimental Biology • Supplementary information

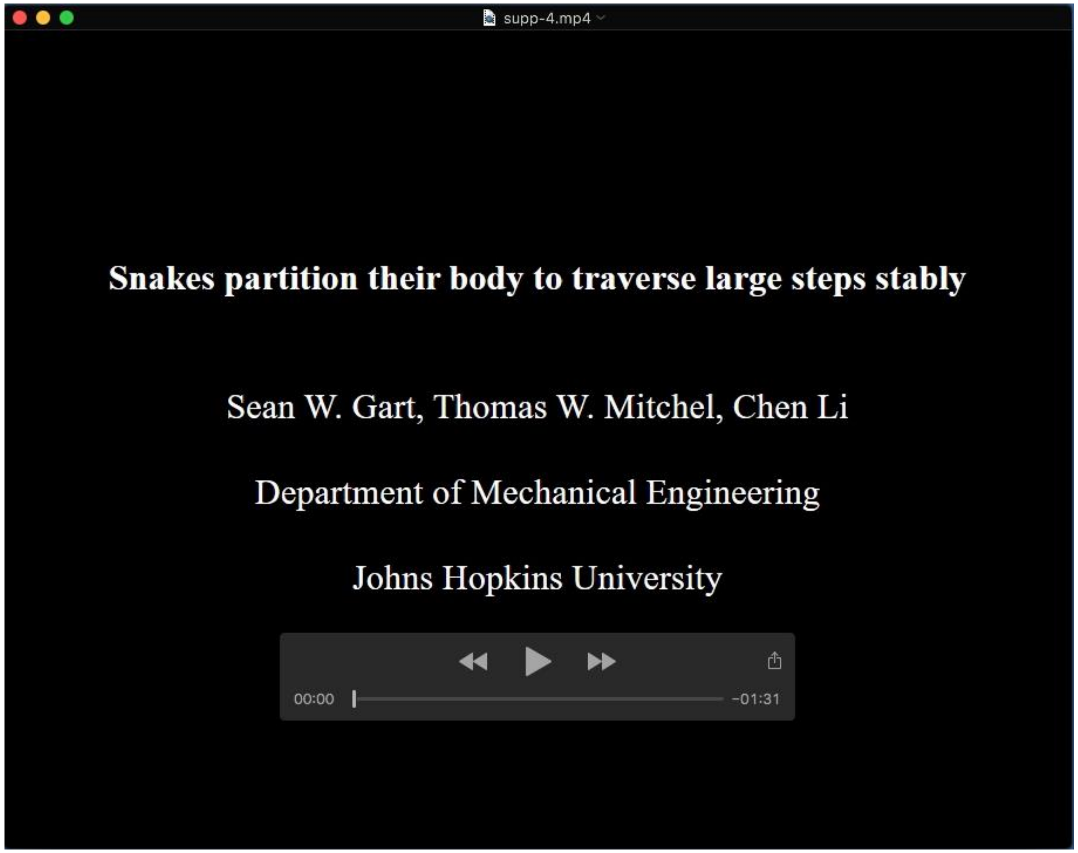


Movie 1. A kingsnake partitions its body to traverse a large step obstacle. The four video clips are for a high friction 15% SVL step (part 1), a high friction 30% SVL step (part 2), a low friction 15% SVL step (part 3), and a low friction 30% SVL step (part 4), respectively.

Journal of Experimental Biology • Supplementary information

Movie 2. A kingsnake maintains static stability throughout the traversal of a large step using body partitioning.

Journal of Experimental Biology • Supplementary information



Movie 3. A kingsnake partitions its body to traverse other complex 3-D terrain. The three video clips are for traversing a large step downward (part 1), a large gap (part 2), and rough terrain (part 3), respectively. Parts 1 and 2 credit: Qiyuan Fu.