

Correspondence

Lasso locomotion expands the climbing repertoire of snakes

Julie A. Savidge^{1,3,*},
Thomas F. Seibert^{1,3}, Martin Kastner¹,
and Bruce C. Jayne^{2,3,*}

The diverse ways and environments in which animals move are correlated with morphology¹, but morphology is not sufficient to predict how animals move because behavioral innovations can create new capacities. We document a new mode of snake locomotion — ‘lasso locomotion’ — that allows the brown treesnake (*Boiga irregularis*) to ascend much larger smooth cylinders than any previously known behavior. This lasso locomotion may facilitate exploiting resources that might otherwise be unobtainable and contribute to the success and impact of this highly invasive species.

The snakes climbed smooth, vertical cylinders (15–20 cm diameter) using a lasso-like body posture, in which the head and neck were oriented uphill of a posterior body loop that encircled and gripped the cylinder (Figure 1A; Video S1). The body always crossed over itself at least once, but the exact body configuration in this region varied considerably. Despite having a transient static grip, some downward sliding of the loop was common (Figure 1C; Figure S1A). Within the loop, small bends to the left and right propagated posteriorly (Figure 1B; Video S1). These bends provided the propulsive mechanism by moving part of the body uphill while simultaneously shifting grip location. The upward velocities per cycle were extremely low (mean = 0.40 cm/s [0.3% total lengths/s]; n = 5 snakes; Figure S1B), and because snakes paused frequently (Figure 1D; Video S1), rates of upward movement over a longer time scale were considerably slower (Figure S1C). Slow speeds, slipping, frequent pausing and heavy breathing during pauses all suggest lasso locomotion is demanding.

Arboreal animals face mechanical challenges including maintaining

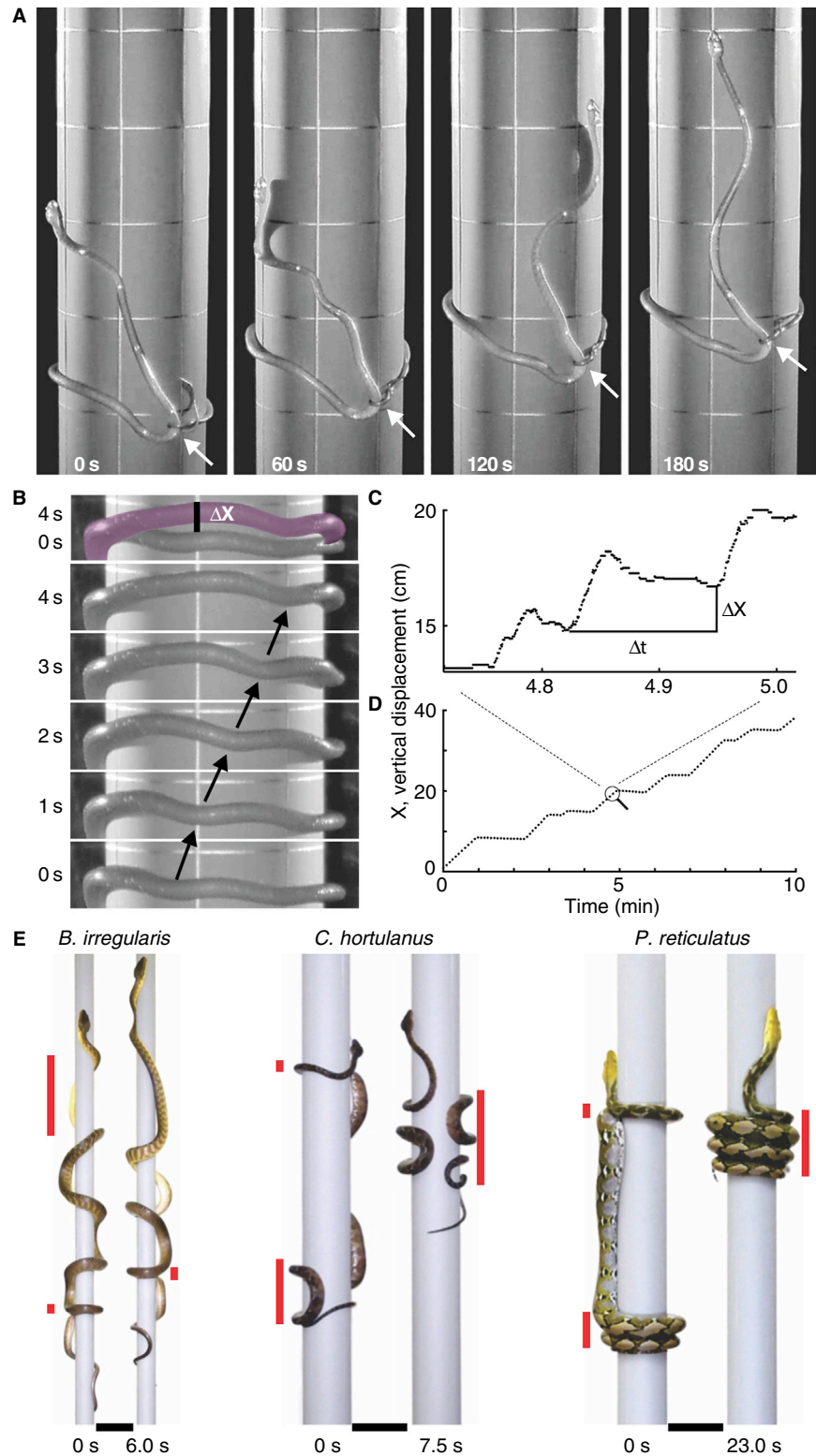


Figure 1. Movements and postures of snakes climbing smooth vertical cylinders.

(A–D) Lasso locomotion of *B. irregularis* (total length, L = 129 cm) climbing a 15.2-cm diameter cylinder. (A) Infrared video images showing the overall posture. White arrows indicate crossover regions. (B) Propagation of lateral bending (black arrows) within the loop of the lasso. The composite image at top shows the amount of vertical displacement (legend continued on next page)



balance and preventing slipping on surfaces of varying slopes and sizes. Without claws or adhesive structures, snakes climbing smooth surfaces rely on gripping with friction, as do many species of primates². However, unlike the fixed length of digits in primates and many other limbed arboreal animals, the elongate and flexible body of snakes provides an exquisite ability to modulate the curvature and length of their gripping area.

The 'lasso locomotion' used by brown treesnakes circumvents many functional challenges for gripping and climbing large vertical cylinders. During all observed types of arboreal concertina locomotion³, including brown treesnakes climbing small to intermediate cylinders, an uphill grip is established before releasing the downhill grip while a significant portion of the body slides between these two gripping regions (Figure 1E; Video S1); each of these regions requires a length of snake approximately as long as the cylinder circumference. Using a single large loop (Figure S1C) to grip, lasso locomotion allows snakes to climb cylinders more than twice the diameter than would otherwise be possible (Figure 1A,E). The small lateral bends within the loop provide two additional advantages: first, a mechanism for shifting grip location while maintaining muscular tension in the loop that could contribute to the normal gripping force on the cylinder; second, possibly allowing snakes to generate tension within the loop using their lateral flexors, which have a much larger cross-sectional area than the ventral flexors⁴. Finally, formation of a crossover region that creates an interlocking structure appears to enhance gripping, as no snake successfully climbed large cylinders without doing so.

For nearly 100 years, all snake locomotion has been traditionally categorized into four modes: rectilinear, lateral undulation, sidewinding, and concertina. Of these modes, only concertina locomotion involves actively generating a friction grip³. Despite lasso

locomotion also having friction gripping, it differs from arboreal concertina locomotion in several ways: it lacks large periodic changes in the overall head-to-tail distance that occur from the body alternately becoming convoluted and then extending; it lacks progressive increases and subsequent decreases in the proportion of the body forming the grip; it lacks the formation of an uphill grip before releasing the downhill grip; and it involves lateral bends that propagate along the body within the loop that forms the gripping region (Figure 1; Video S1). Thus, instead of being a subcategory of concertina locomotion³ or resembling any other previously described category, lasso locomotion is a new and distinct mode of snake locomotion.

The ability to move in diverse settings impacts an animal's potential to exploit resources, and key factors affecting arboreal locomotion are surface roughness, steepness and branch diameter⁵. For example, the rat snake, *Pantherophis obsoletus*, cannot climb large, smooth trunks of *Quercus nuttallii*, which may account for preferential use and higher success of birds nesting in that tree⁶. Similarly, brown treesnakes and other snake species cannot climb large diameter (>70 cm) smooth-bark trees harboring communally-nesting starlings in Australia⁷. Brown treesnakes evolved in this and nearby humid tropical regions. While they could not climb these very large trees, lasso locomotion would facilitate climbing trees within their body length limits and allow access to prey that may not be available to less capable snake species.

Versatility of locomotor behaviors and capabilities may enhance the breadth of potential and realized ecological niches and exacerbate ecological impacts of invasive species. In addition to lasso locomotion, brown treesnakes are adept at: bridging large gaps, swimming, using lateral undulation to climb steep surfaces with 1-mm projections and crawling on branches and wires that are a small fraction of their body diameter^{5,8}.

Collectively, these abilities contribute to their detrimental ecological and economic impacts, such as decimating the native vertebrate fauna of Guam⁹ and short-circuiting electrical lines¹⁰.

Lasso locomotion illustrates how a behavioral innovation can potentially permit exploitation of resources that would otherwise be unavailable. This knowledge can be applied to the protection of native species and vulnerable infrastructure. Lastly, our findings provide an example of how the evolution of behavior can radically modify functional capacity and versatility.

SUPPLEMENTAL INFORMATION

Supplemental Information includes experimental procedures, acknowledgements, one figure and one video can be found online at <https://doi.org/10.1016/j.cub.2020.11.050>.

A video abstract is available at <https://doi.org/10.1016/j.cub.2020.11.050#mmc3>.

REFERENCES

- Dickinson, M.H., Farley, C.T., Full, R.J., Koehl, M.A.R., Kram, R., and Lehman, S. (2000). How animals move: an integrative view. *Science* 288, 100–106.
- Cartmill, M. (1985). Climbing. In *Functional Vertebrate Morphology*, M. Hildebrand, D.M. Bramble, K.F. Liem and D.B. Wake, eds. (Cambridge: Belknap Press), pp. 73–88.
- Jayne, B.C. (2020). What defines different modes of snake locomotion? *Integr. Comp. Biol.* 60, 156–170.
- Jorgensen, R.M., and Jayne, B.C. (2017). Three-dimensional trajectories affect the epaxial muscle activity of arboreal snakes crossing gaps. *J. Exp. Biol.* 220, 3545–3555.
- Jayne, B.C., Newman, S.J., Zentkovich, M.M., and Berns, H.M. (2015). Why arboreal snakes should not be cylindrical: body shape, incline and surface roughness have interactive effects on locomotion. *J. Exp. Biol.* 218, 3978–3986.
- Mullin, S.J., and Cooper, R.J. (2002). Barking up the wrong tree: climbing performance of rat snakes and its implications for depredation of avian nests. *Can. J. Zool.* 80, 591–595.
- Natusch, D.J.D., Lyons, J.A., and Shine, R. (2017). Safety first: terrestrial predators drive selection of highly specific nesting sites in colonial-breeding birds. *J. Avian Biol.* 48, 1104–1113.
- Byrnes, G., and Jayne, B.C. (2012). Three-dimensional trajectories affect gap bridging performance and behavior of brown tree snakes (*Boiga irregularis*). *J. Exp. Biol.* 215, 2611–2620.
- Savidge, J.A. (1987). Extinction of an island forest avifauna by an introduced snake. *Ecology* 68, 660–668.
- Rodda, G.H., Sawi, Y., Chiszar, D., and Tanaka, H. (1999). *Problem Snake Management: The Habu and the Brown Treesnake* (Ithaca: Cornell University Press).

¹Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA. ²Department of Biological Sciences, PO Box 210006, University of Cincinnati, Cincinnati, OH 45221, USA. ³These authors contributed equally.

*E-mail: Julie.Savidge@colostate.edu (J.A.S.); jaynebc@ucmail.uc.edu (B.C.J.)

(thick black line) during the propulsive phase of a cycle. (D) Vertical displacement versus time during a long climb with pauses, and (C) approximately three cycles of continuous movement within the longer climb. The duration and net vertical displacement for one cycle are indicated by Δt and ΔX , respectively. (E) Pairs of video images showing less than one cycle of movement of *B. irregularis* (L = 201 cm), *Corallus hortulanus* (L = 173 cm) and *Python reticulatus* (L = 197 cm) climbing with previously described variants of concertina locomotion³ and making greater upward progress per cycle than lasso locomotion. Black scale bar = 10 cm, and the thick red, vertical lines indicate regions of static gripping.