Introduction

A moving topic: control and dynamics of animal locomotion

Andrew Biewener1 and Thomas Daniel2,*

1Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 01730, USA
2Department of Biology, University of Washington, Seattle, WA 98195, USA
*Author for correspondence (danielt@u.washington.edu).

Animal locomotion arises from complex interactions among sensory systems, processing of sensory information into patterns of motor output, the musculo-skeletal dynamics that follow motor stimulation, and the interaction of appendages and body parts with the environment. These processes conspire to produce motions and forces that permit stunning manoeuvres with important ecological and evolutionary consequences. Thus, the habitats that animals may exploit, their ability to escape predators or attack prey, their capacity to manoeuvre and turn, or the use of their available energy all depend upon the processes that determine locomotion. Here, we summarize a series of 10 papers focused on this integrative research topic.

Keywords: animal locomotion; sensory systems; motor control; biomechanics

Animal locomotion arises from complex interactions among sensory systems, processing of sensory information into patterns of motor output, the musculo-skeletal dynamics that follow motor stimulation and the interaction of appendages and body parts with the environment. These processes conspire to produce motions and forces that permit stunning manoeuvres with important ecological and evolutionary consequences. Thus, the habitats that animals may exploit, their ability to escape predators or attack prey, their capacity to manoeuvre and turn, or the use of their available energy all depend upon the processes that determine locomotion. Here, we summarize a series of 10 papers focused on this integrative research topic.

Keywords: animal locomotion; sensory systems; motor control; biomechanics

One contribution of 11 to a Special feature on ‘Control and dynamics of animal movement’.

Received 26 March 2010
Accepted 29 March 2010

387 This journal is © 2010 The Royal Society
properties that depend upon the forces it experiences. Here, they examine the locomotion of hatchling loggerhead sea turtles (Caretta caretta), showing that compaction of loose sand by the flipper enables equally effective locomotion as that obtained by traction using their flipper’s claw when moving over a solid sandpaper substrate.

The second group of three papers is concerned with sensory information processing in the control of animal locomotion. All three papers focus on the ability of nervous systems to encode information at rates and magnitudes that are critical for movement control. In a study of the lateral line in larval zebrafish, Liao (2010) combines single cell imaging and electrophysiological methods with biomechanical manipulations to reveal fine-tuned sensitivity of mechanosensory cells to local flow direction and velocity. In a similar vein, but at a larger scale of motion, Sane et al. (2010) question how mechanosensory information determines flight paths in migratory insects. Using a combination of field behaviour and experimental manipulation of sensory systems, they show that long-distance migration requires mechanosensory input mediated through antennae in addition to visual information. Vision, in turn, is the focus of the paper by Theobald et al. (2010). Using a flight simulator that provides abrupt perturbations to otherwise smooth motion in the visual world of a tethered fruitfly, these authors show that compensatory reflexive responses to sideways motion depends upon the overall visual flow experienced by the animal as a result of its own body movement (forward, backward or sideways).

The final group of papers focuses on the emergent motions of animal appendages and their role in locomotion. Dadda et al. (2010) question whether motor output may be lateralized in the brain of fish. Using a time-tested experimental paradigm of escape locomotion in fish subject to mechanical stimulation, they show lateralization—determined by turning direction preference—leads to lower latency in the motor output associated with escape. That may be a consequence of either motor-patterning or sensory processing. In terrestrial systems, motor-patterning combined with the biomechanics of limbs plays a key role in gaits that may conserve energy and provide stability. Thus, Daley & Usherwood (2010) use a theoretical approach to explore how limb compliance combined with the control of limb positions (extensions and velocities) allows for effective control of stability during locomotion over uneven terrain while maintaining appropriate bounds on energy utilization.

This theme of limb control continues into the air with two additional papers on insect flight, both focusing on manoeuvrability. Hedrick & Robinson (2010) draw on prior work that has shown that, as an animal turns, the interaction between wing-flapping and body rotation leads to a counter torque that provides inherent stability, without any special asymmetry in wing-flapping. In their paper here, they show that this stabilizing dynamic applies across multiple wing strokes in a continuous sustained turn. In the paper by Combes et al. (2010), the focus turns more towards the ecological implications of flight performance in relation to wing-flapping dynamics. Interestingly, many studies have shown that animals are capable of flying with incredible reductions in wing area. However, none have clearly shown whether flight is somehow compromised by wing damage. Using a combination of experimental manipulations on dragonflies, they ask if the damage that naturally occurs to wings has any measurable fitness consequences. By directly measuring prey capture success of dragonflies with and without partial wing loss, they provide the first clear demonstration of an ecological consequence of natural wing reductions.

We thank all of the contributors to this volume for their exciting papers. We also extend our deep appreciation to Ms Fiona Pring for her untiring attention to detail and inspiration for this Special feature. T.L.D. is supported by the Richard and Joan Komen Endowed Chair at the University of Washington.


