Animal Locomotion

Introduction to Biomechanics
2008/11/26

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MOVEMENT: MOLECULAR TO ROBOTIC
REVIEW

How Animals Move: An Integrative View

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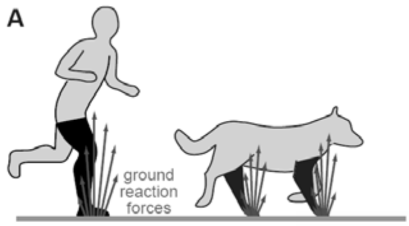
Recent advances in integrative studies of locomotion have revealed several general principles. Energy storage and exchange mechanisms discovered in walking and running bipeds apply to multilegged locomotion and even to flying and swimming. Nonpropulsive lateral forces can be sizable, but they may benefit stability, maneuverability, or other criteria that become apparent in natural environments. Locomotor control systems combine rapid mechanical preflexes with multimodal sensory feedback and feedforward commands. Muscles have a surprising variety of functions in locomotion, serving as motors, brakes, springs, and struts. Integrative approaches reveal not only how each component within a locomotor system operates but how they function as a collective whole.

I. Forcing the Issue–

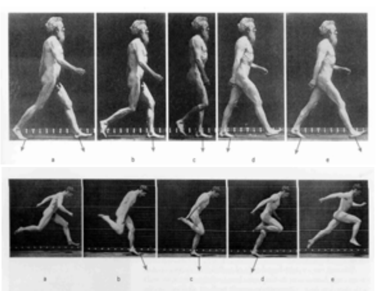
Forces during locomotion vary in space & time

Ground reaction forces



- GRF vectors– equal time interval
- Braking → propulsion
- @ each instance, resultant vector points to the hip (shoulder) of each leg→ ↓ torque at each joint

Walking vs. Running

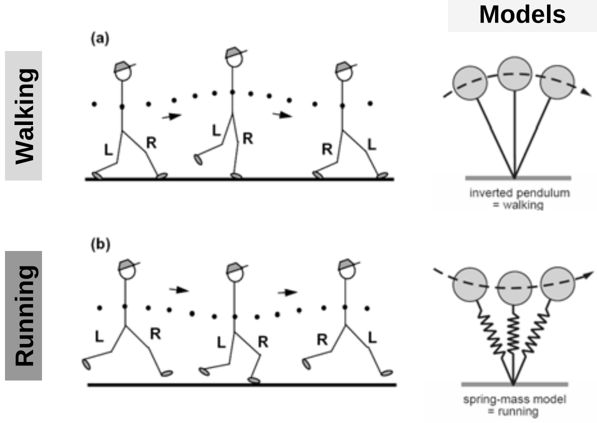


Photographed by Eadweard Muybridge in 1880's

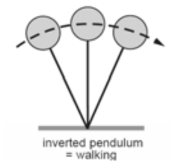
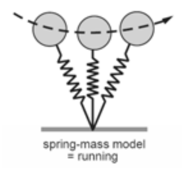
Alexander, *Exploring Biomechanics: Animal in Motion*

What are the difference?

Models



Vogel, *Comparative Biomechanics*: Life's Physical World

	Models	**Energy transformation**
Walking		Potential energy ↔ Kinetic energy
Running		Potential + kinetic energy ↔ Elastic energy

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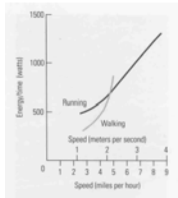
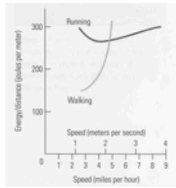
O2 consumption in walking vs. running





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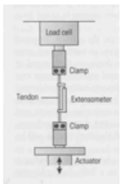
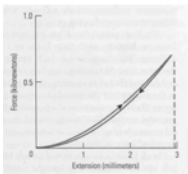
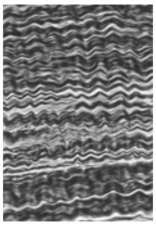
The "spring" in a running step

Major player: tendon





93% energy returned



Collagen fibers in a tendon

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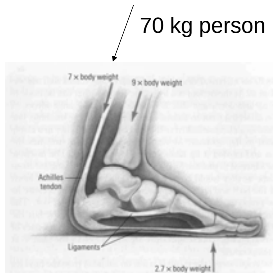
50 kg person → 3500 N

70 kg person → 5000 N



➔ 56 MPa stress

(~ ½ that could break the tendon)

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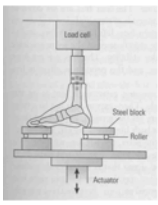
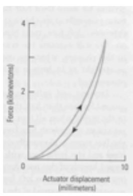
Another player– arch of the human feet





78% energy returned

Total: ½ Energy Saved by two kinds of springs

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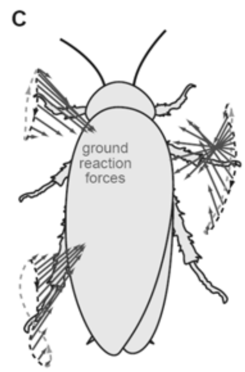
How about lateral forces?



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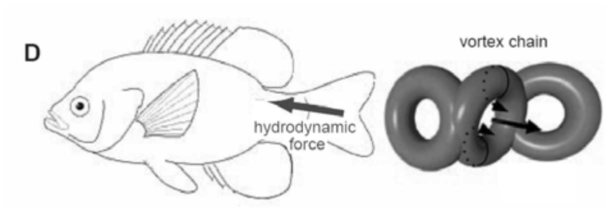
Fish swimming



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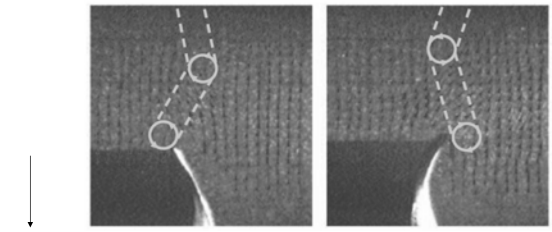

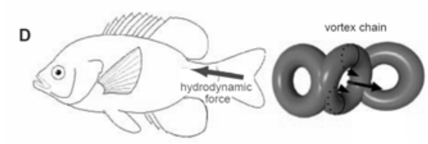

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(Digital) Particle Image Velocimetry [(D)PIV]

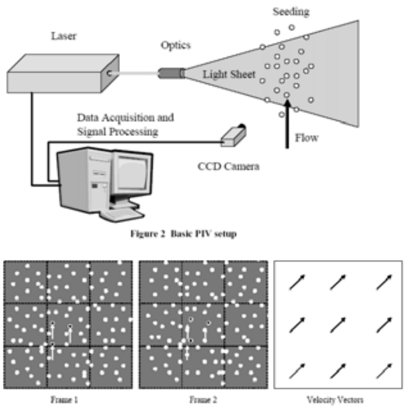

Figure 2 Basic PIV setup

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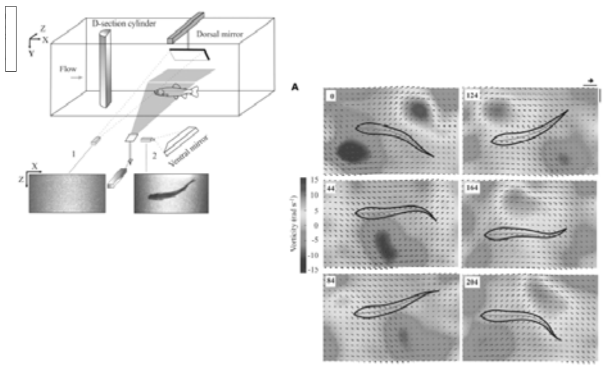
National Institute of Standards and Technology

Example: Liao et al., 2003, *Science*.



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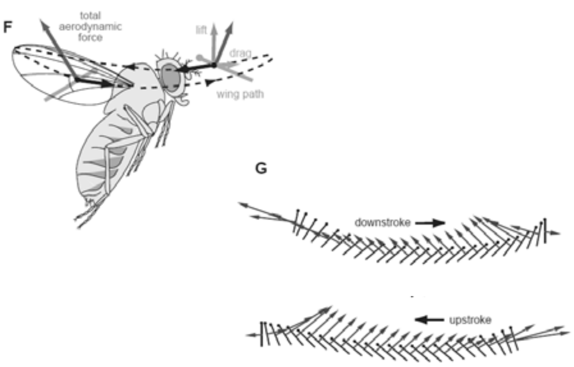
Insect flying



II. Leaving the Straight and Narrow–

Moving in a natural context

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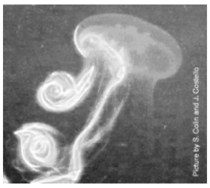
Trade-offs b/w locomotion & other functions

Example:
Swimming jellyfish



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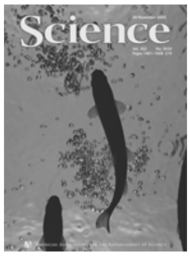
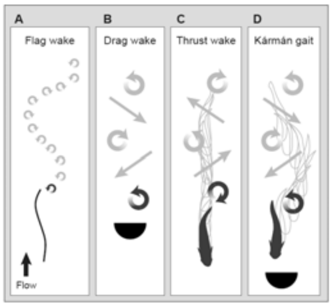
Effects of mechanics of environment





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III. Control Systems Are Closely Coupled

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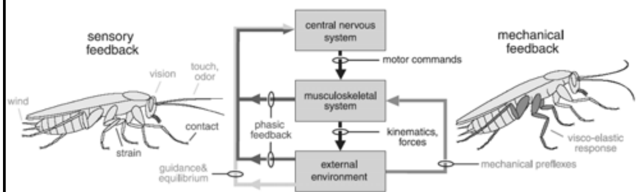
Neural & mechanical feedback of locomotion control



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IV. Muscles Are More Than Motors

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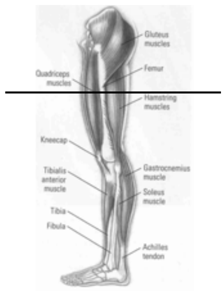
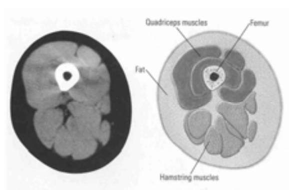
The Anatomy: Muscles in human Leg





Computer-aided tomography (CT) scan

Alexander, *Exploring Biomechanics: Animal in Motion*

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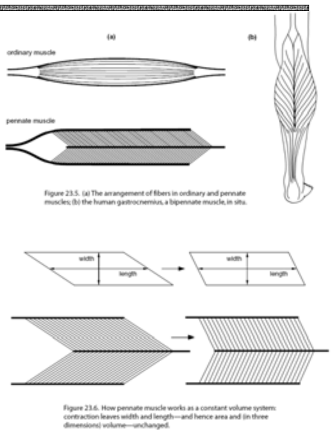
Some important facts about muscles

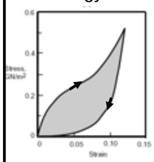
1. Force ∝ cross-sectional area
2. Can only **contract** actively

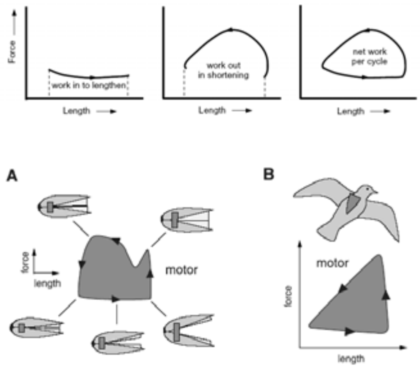


Vogel, *Comparative Biomechanics*

Work loop: Muscle as a engine (work output)

Spider silk–
Energy lost





Vogel, *Comparative Biomechanics*

Muscle also serves as a break (absorb energy)

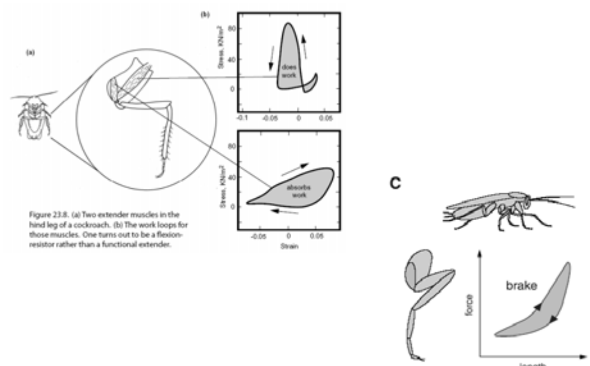
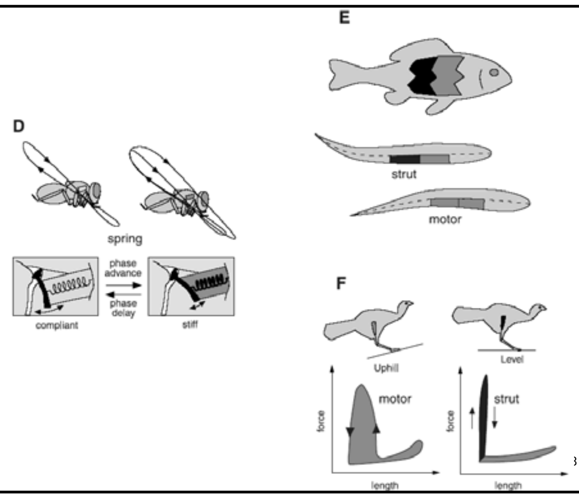


Figure 23.8. (a) Two extender muscles in the hind leg of a cockroach. (b) The work loops for those muscles. One turns out to be a flexion-resistor rather than a functional extender.

Vogel, *Comparative Biomechanics*



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… is dedicated to integrated, interdisciplinary, multi-leveled approaches to the study of animal physiology and behavior.

Current research focuses on the neurobiology and biomechanics of locomotion in flies.

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