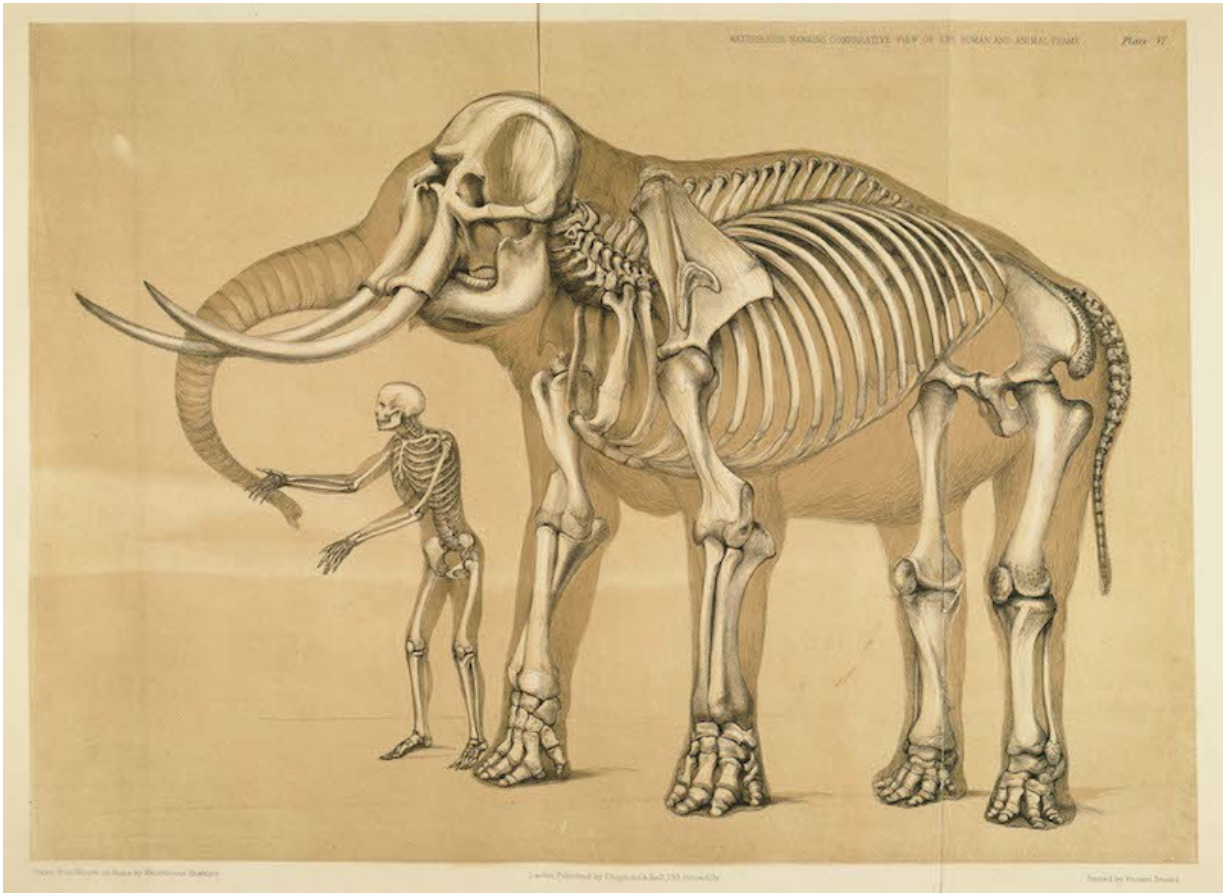
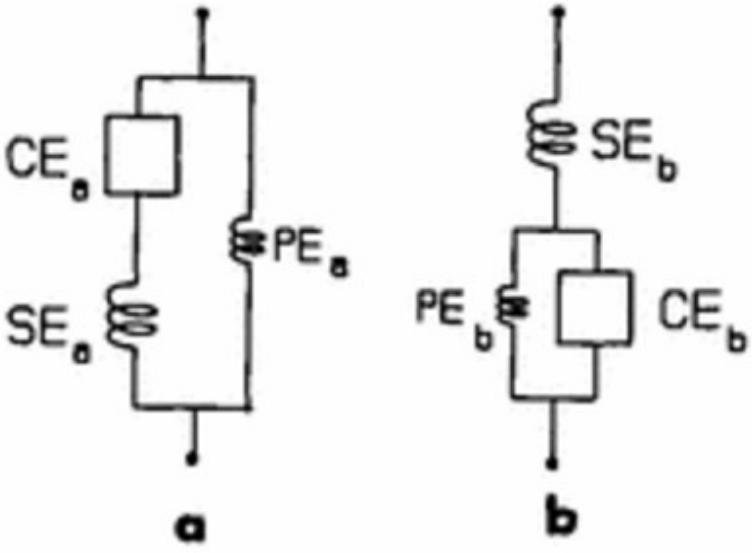
What's (different) in a quadruped?

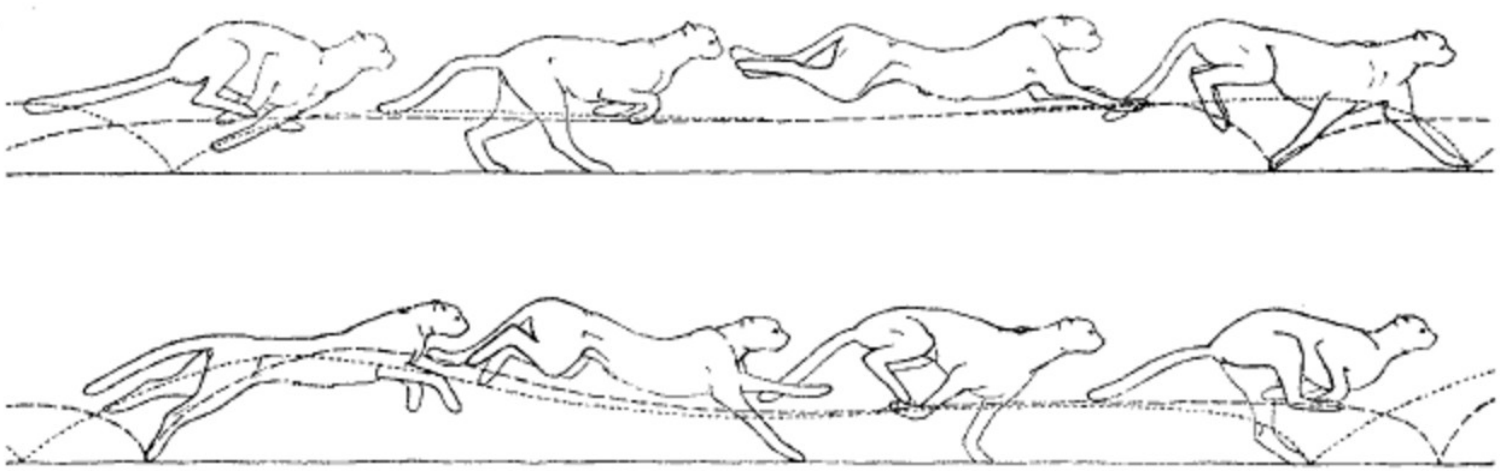


- Leg/foot structure
- Unguligrade, digitigrade, plantigrade
- Tendons, muscles form viscoelastic systems—Winters [1990]

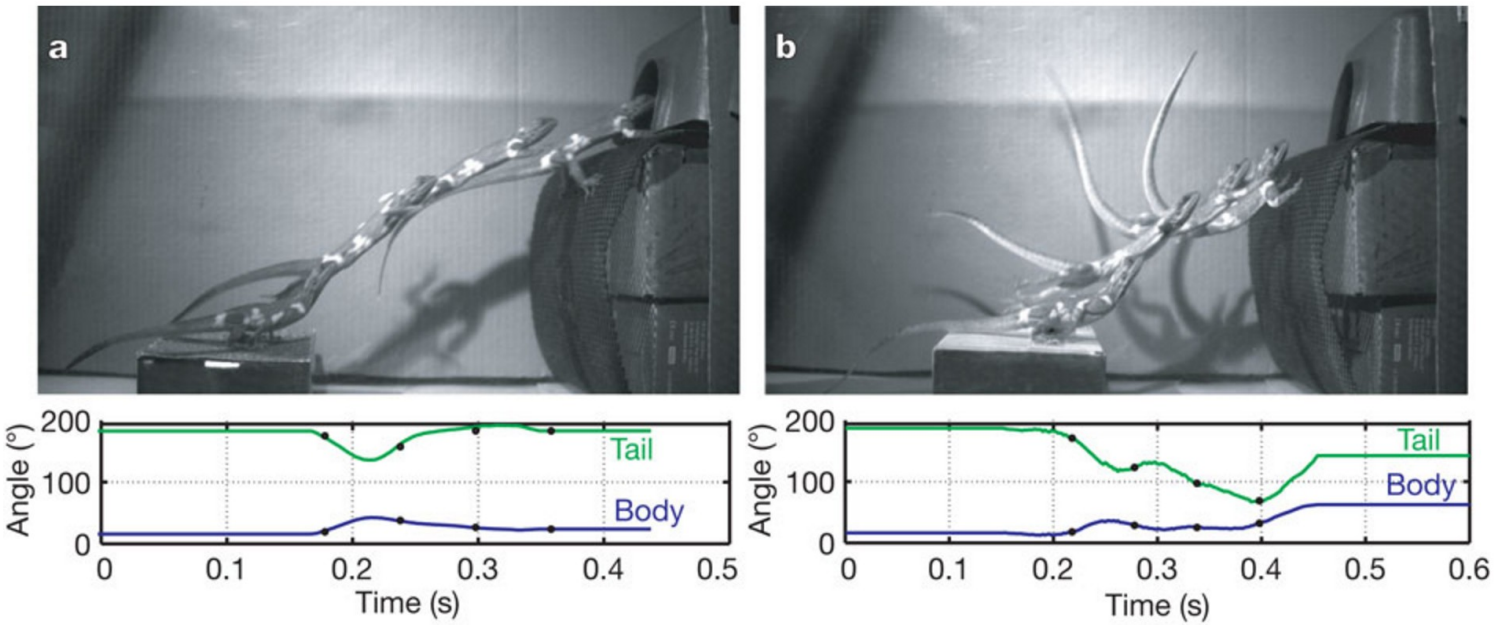


Quadrupeds use their core

From Hildebrand [1961]

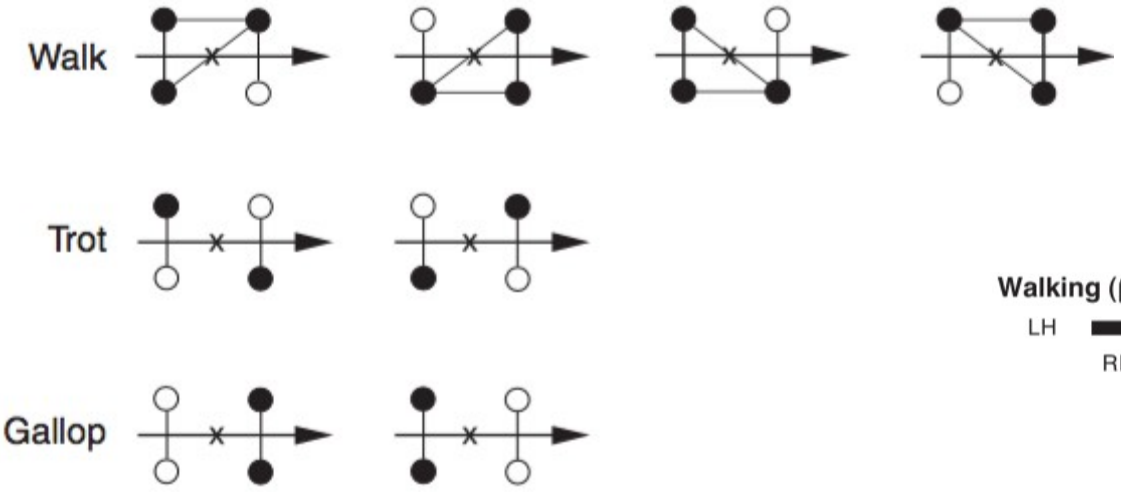


From Libby et al. [2012]

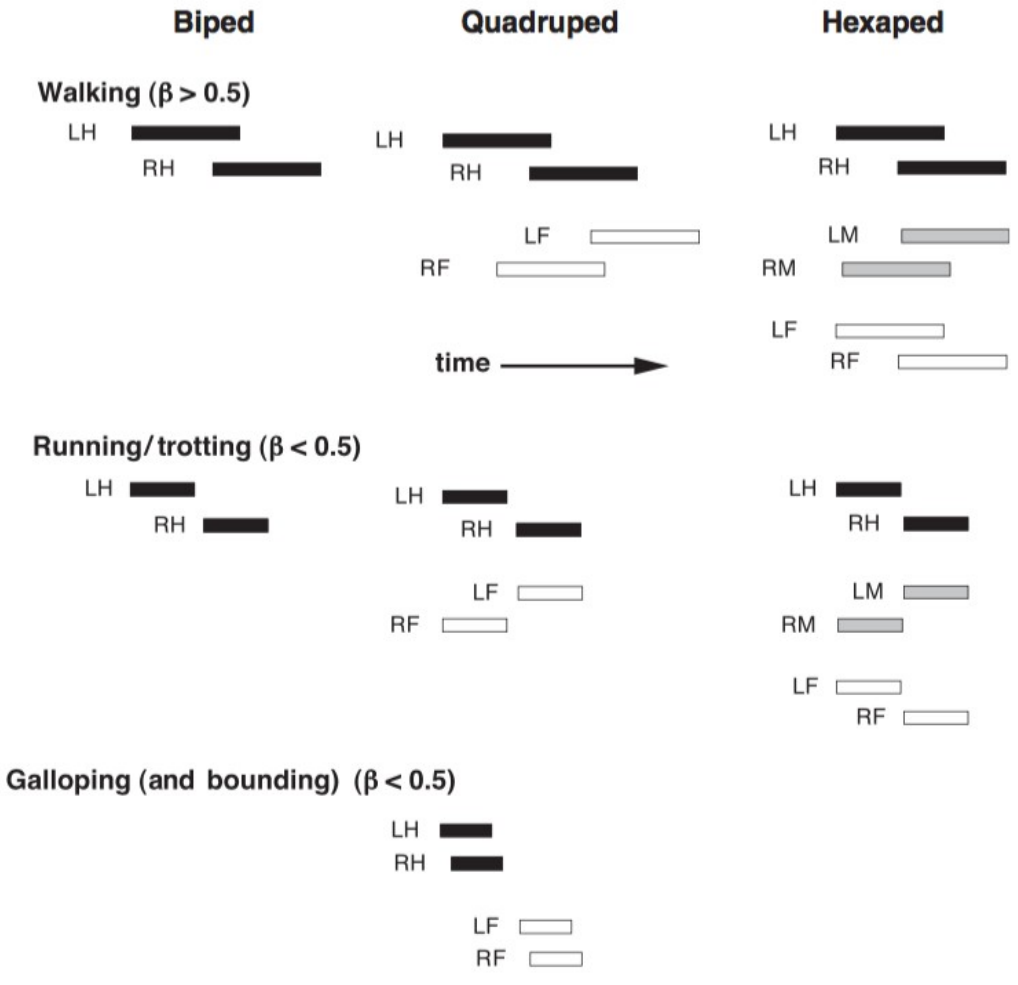


Gaits in nature's quadrupeds

- "Limb support pattern"—Biewener [2003]

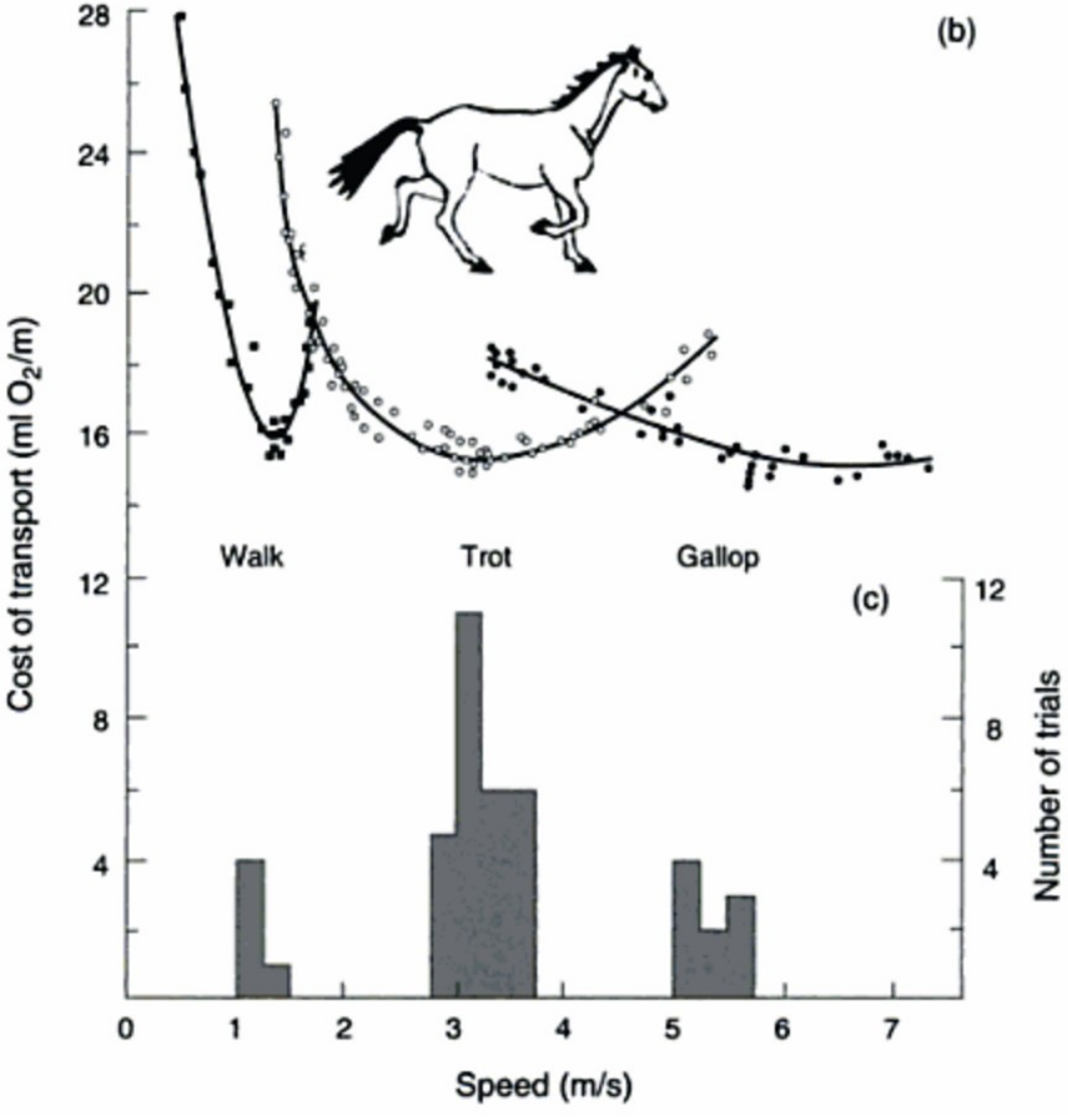


- "Gait diagram"



Gait energetics

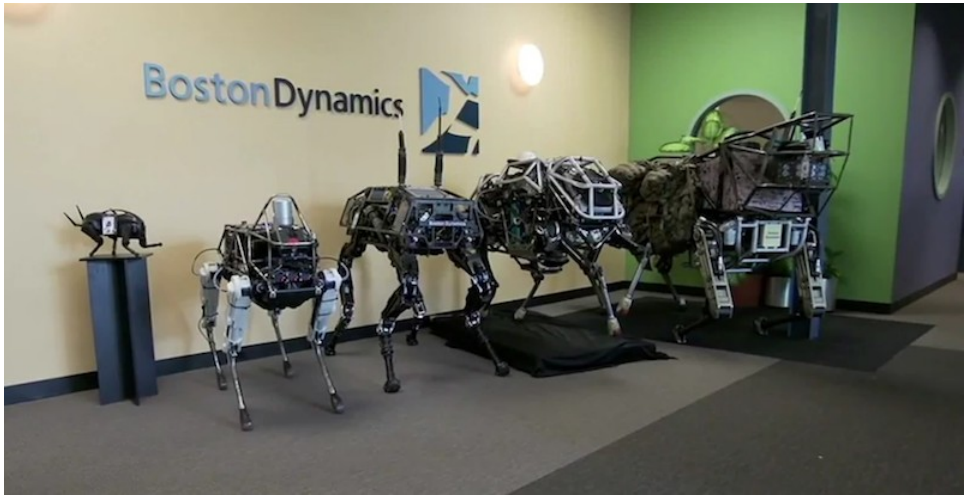
Energetics—Biewener [2003]



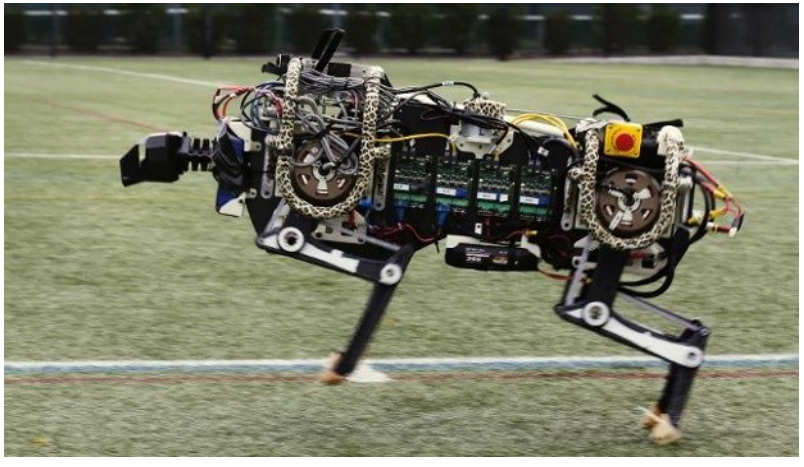
$$\text{CoT} := \frac{\text{metabolic power}}{mgv}$$

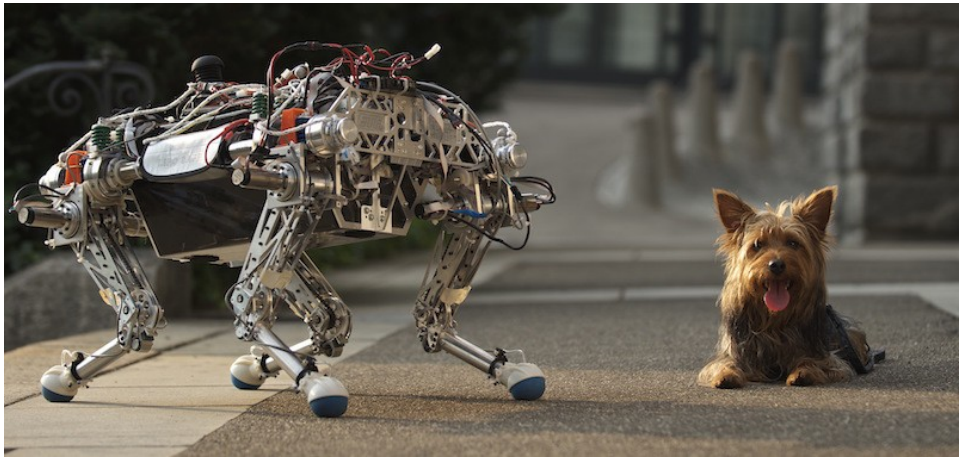
A very short list of other robotic quadrupeds

- Boston Dynamics': LittleDog, Spot, BigDog, WildCat, LS3



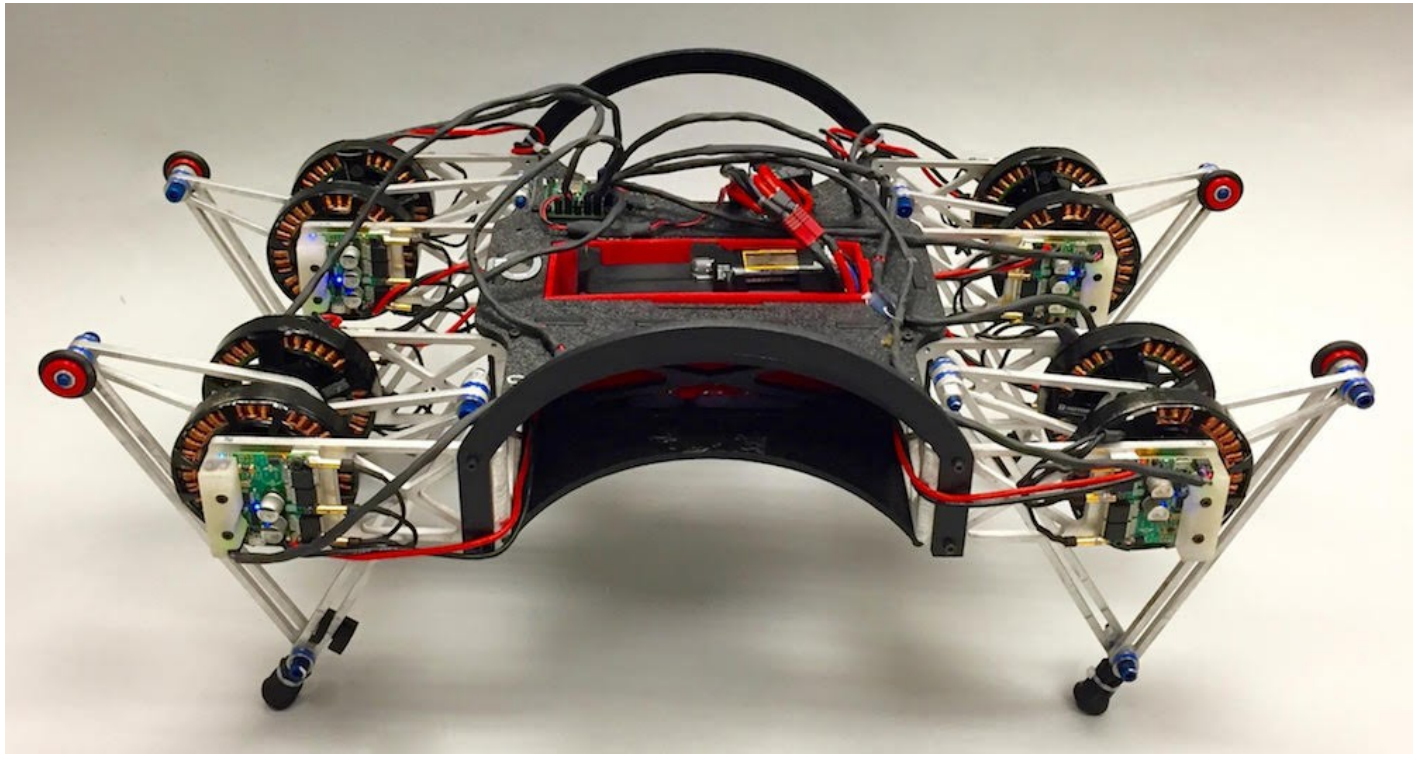
- MIT Cheetah—Seok et al. [2015]
- StarlETH—Hutter et al. [2012]





- And many more…

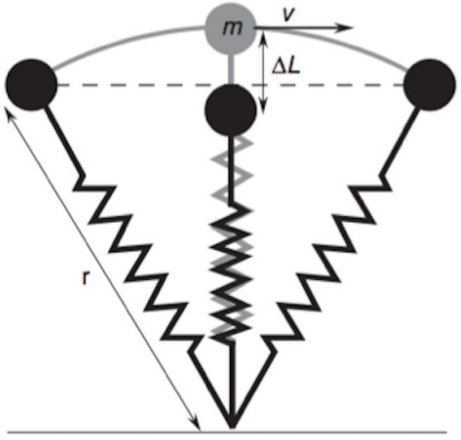
Minitaur

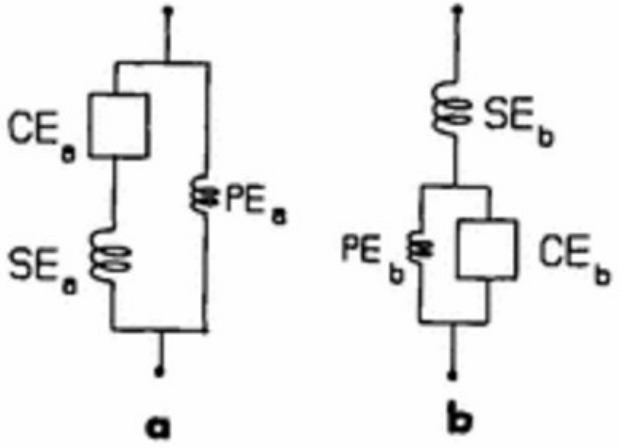


- Task-optimal leg design—Kenneally and Koditschek [2015]
- Direct drive—Kenneally et al. [2015]

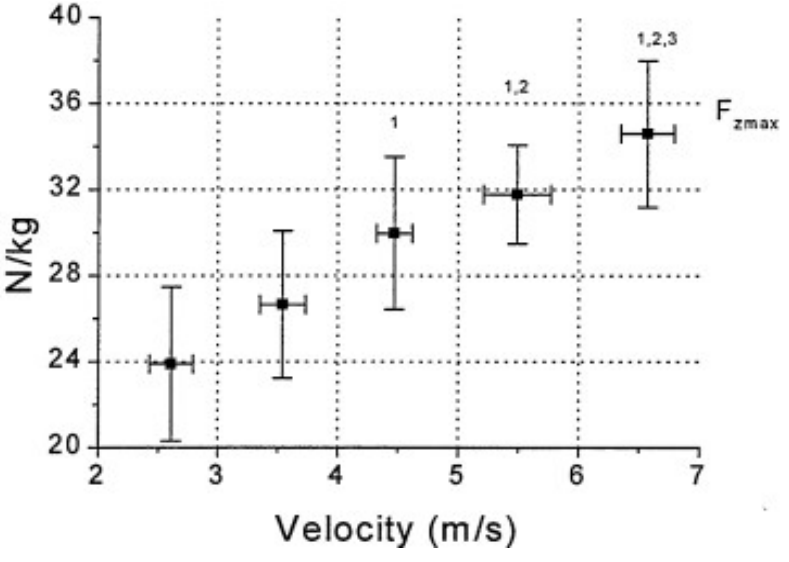
Robot design from the bottom up

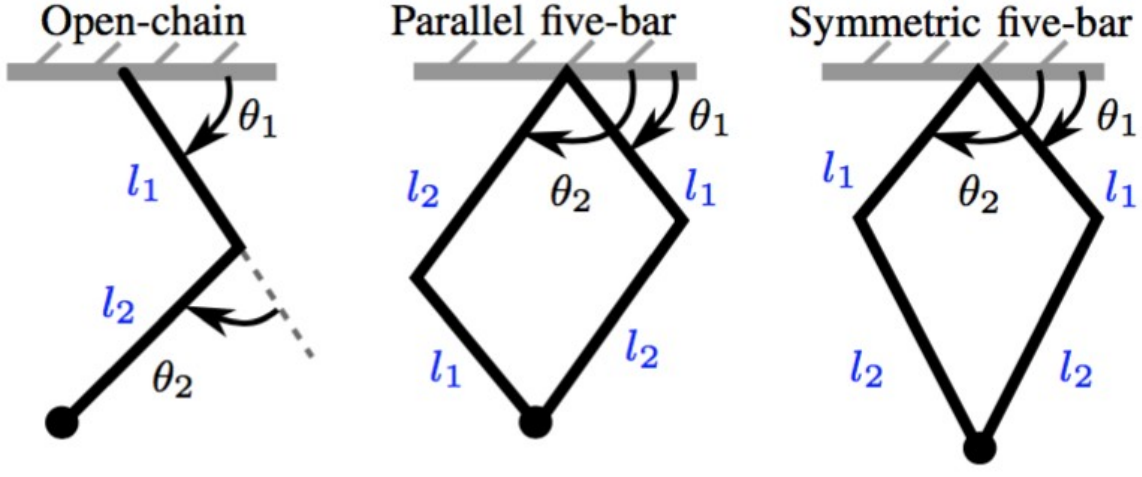
- Recall animal legs





- Tunable stiffness (e.g. human running—Arampatzis et al. [1999])





- Minitaur legs: 2DOF, force transmission, proprioception—Kenneally et al. [2015]

Lessons from quadrupedal animals and robots

Biomechanists tell us

- Legs need to swing, retract—Biewener [2003]
- Gaits emerge from energetics, control needs

Roboticists learn

- Build legs with enough DOFs
- Control ideas varied (more in the last week)
- Spines / tails not popular yet