Biology 427 Biomechanics

Lecture 14. Muscle and energy

- Comments about projects
- Recap force: depends on cross sectional area, time, sarcomere length, and contraction velocity
- In normal movement, neither isometric nor isotonic conditions apply (length and force vary in time)
- The work loop method — how is mechanical energy managed in real systems?
- Timing and activation
- Some final matters on muscle — it is isovolumetric. What might this mean?

Biology 427 Biomechanics

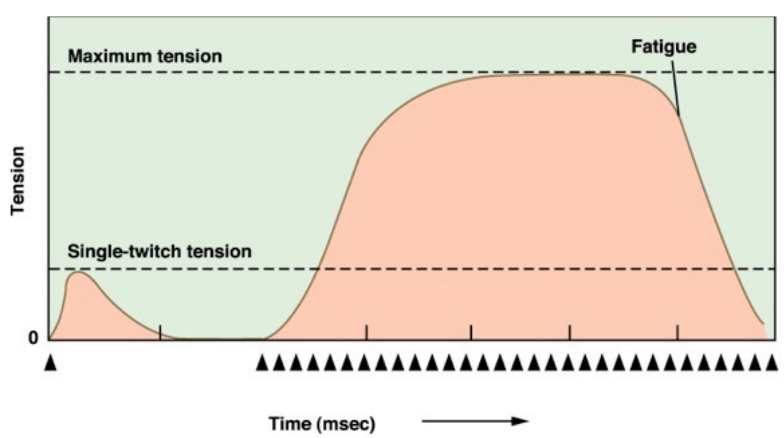
Course projects

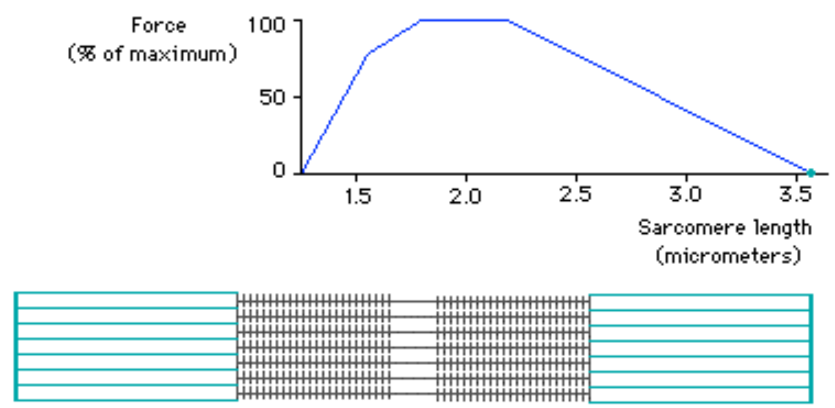
- 20 points
- Any topic that involves mechanics and biology
- It will be in the form of a poster that you will submit online (poster guidelines will be posted)
- Any pair within one lab
- Analytic/experimental work is excellent
- Will use lab during scheduled hours for projects
- Assistance with Mathematica (via TLD) can be had
- Poster template and guidelines Week of Nov 7
- Project proposals due in lab week of Nov 14
- Labs will be open Tues week of Nov 21 for joint work
- Week of Nov 28 is a half lab and half poster prep time.
- Week of Dec 5 poster presentations via power point slides.

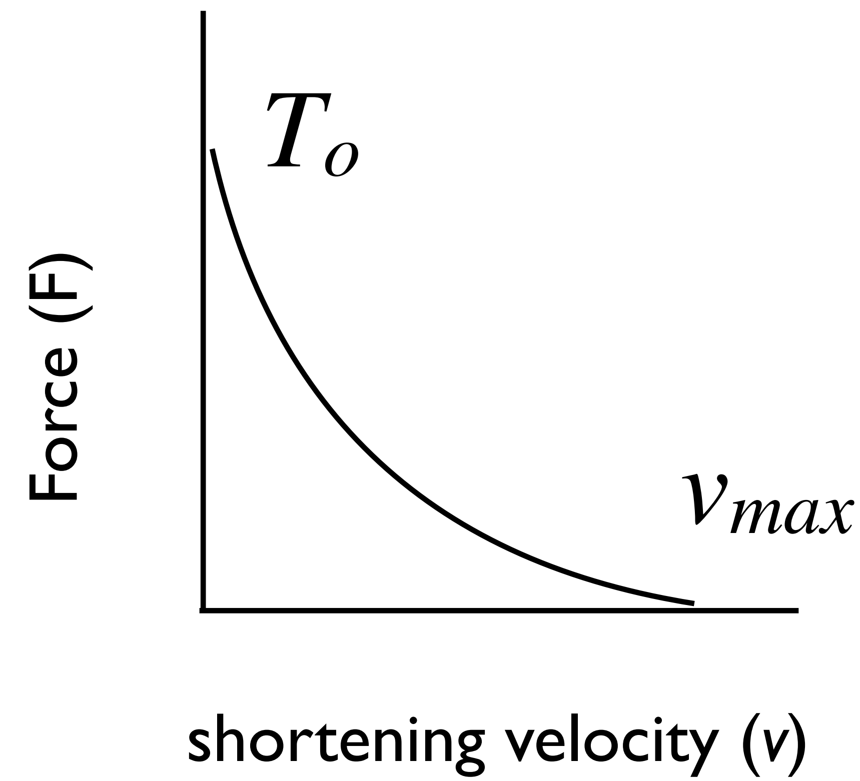
Force is proportional to the cross-sectional area
and timing and length and velocity

Power =force x velocity

$$F = \frac{b\,T_0 - a\,v}{v+b}$$







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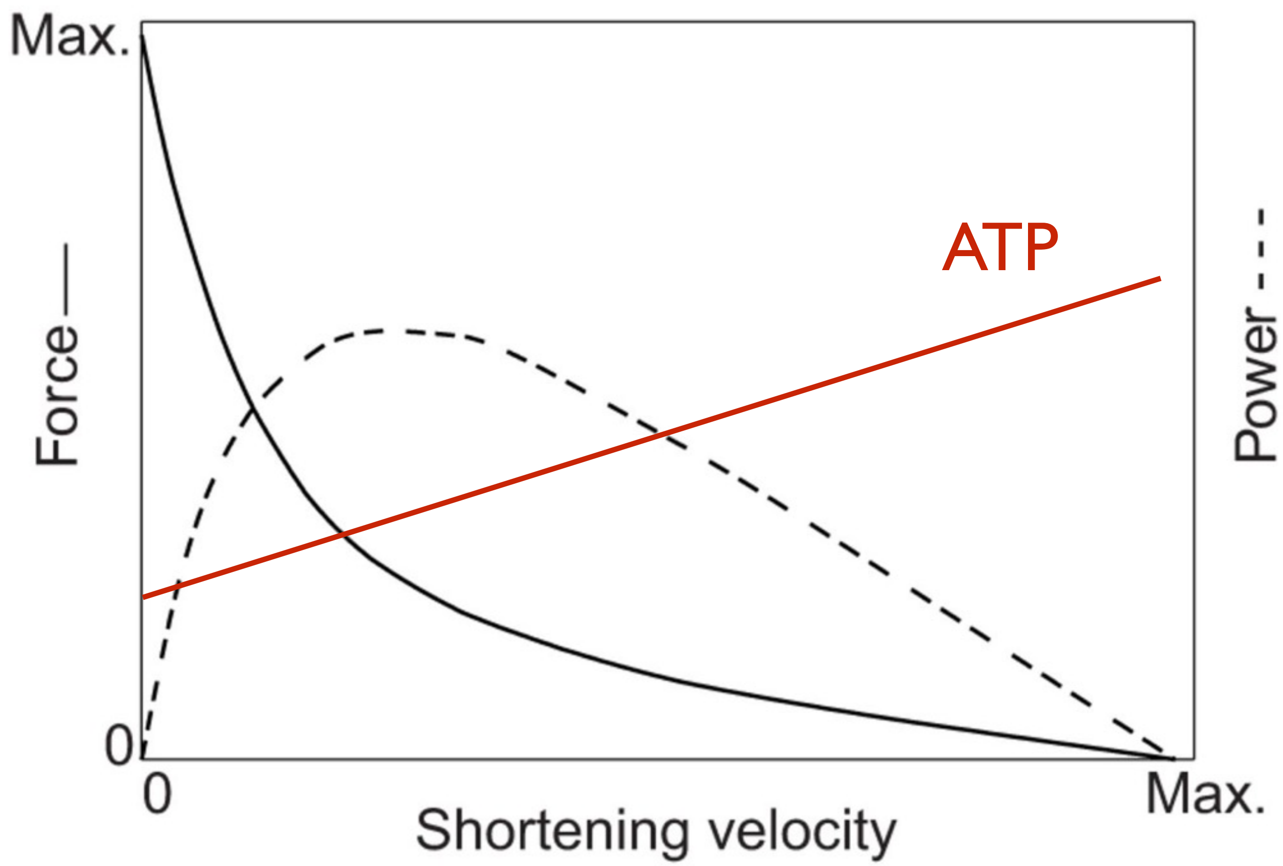

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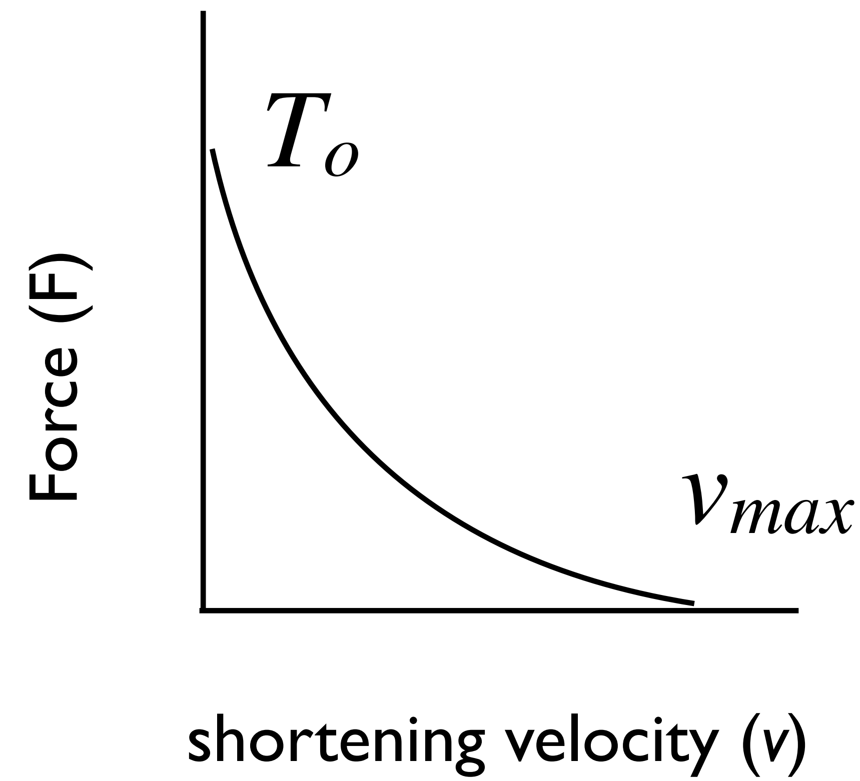
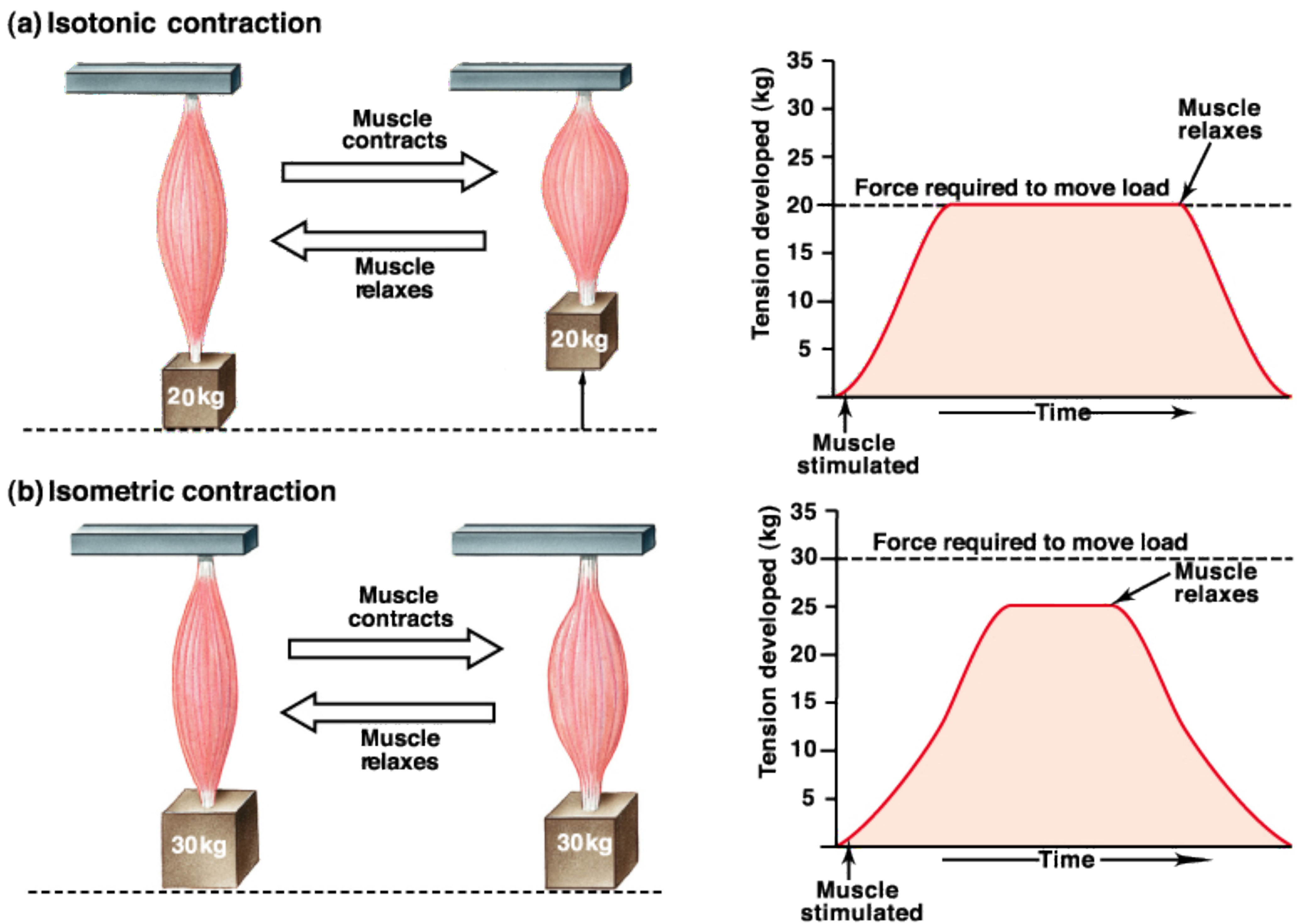


A mathematica demo

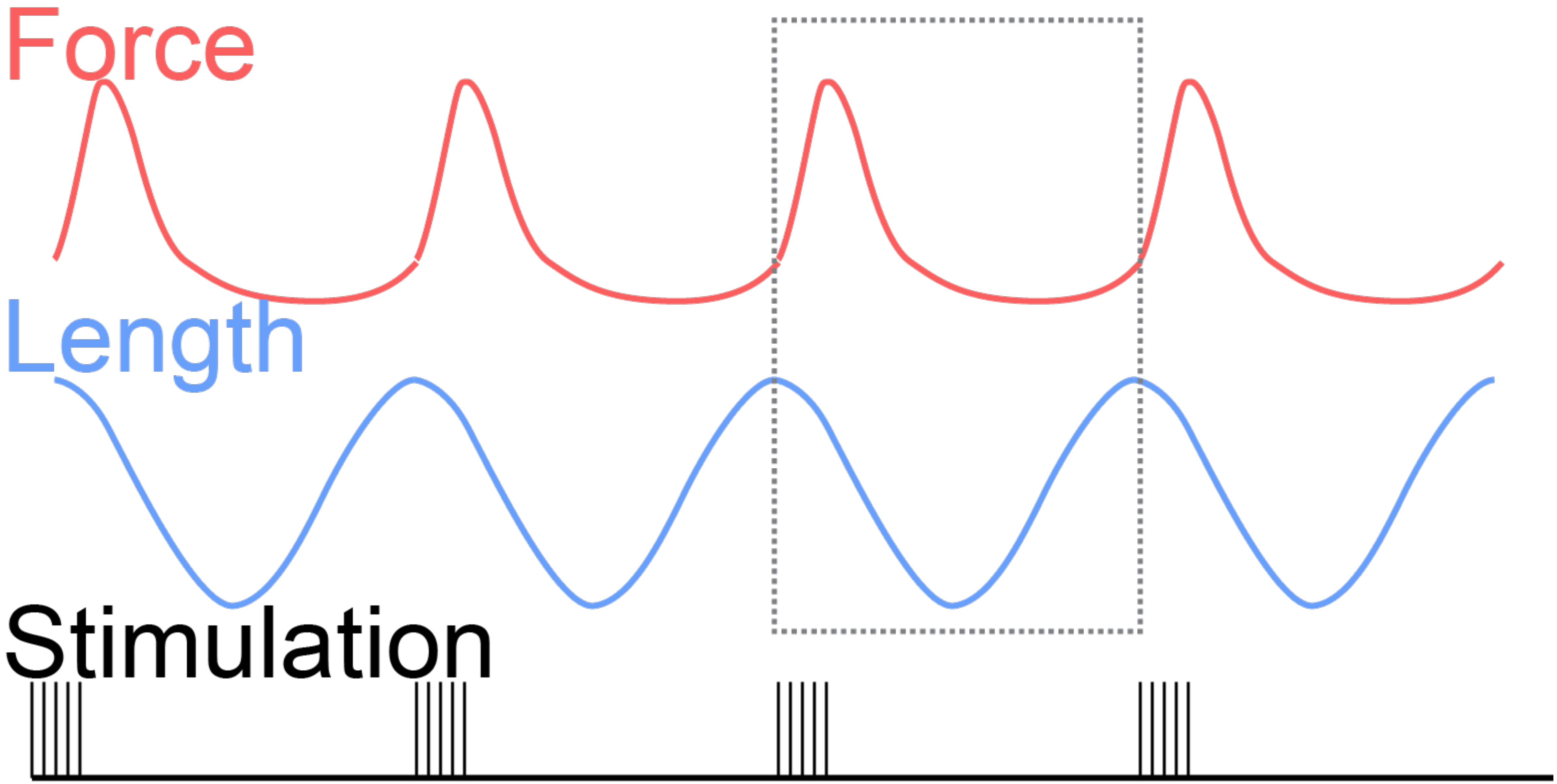
Isometric versus isotonic contractions



Silverthorn, Human Physiology, 2CE

Work loops:

In most movement activities, muscle contraction is neither purely isometric nor isotonic. In class demo…



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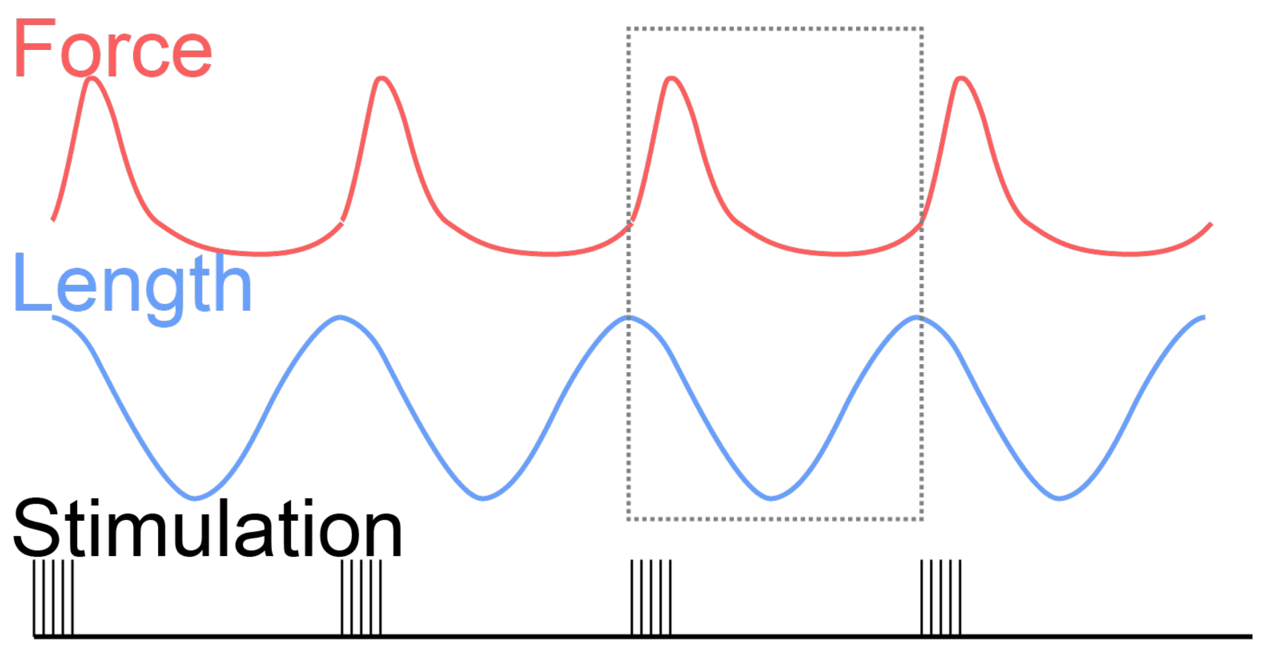
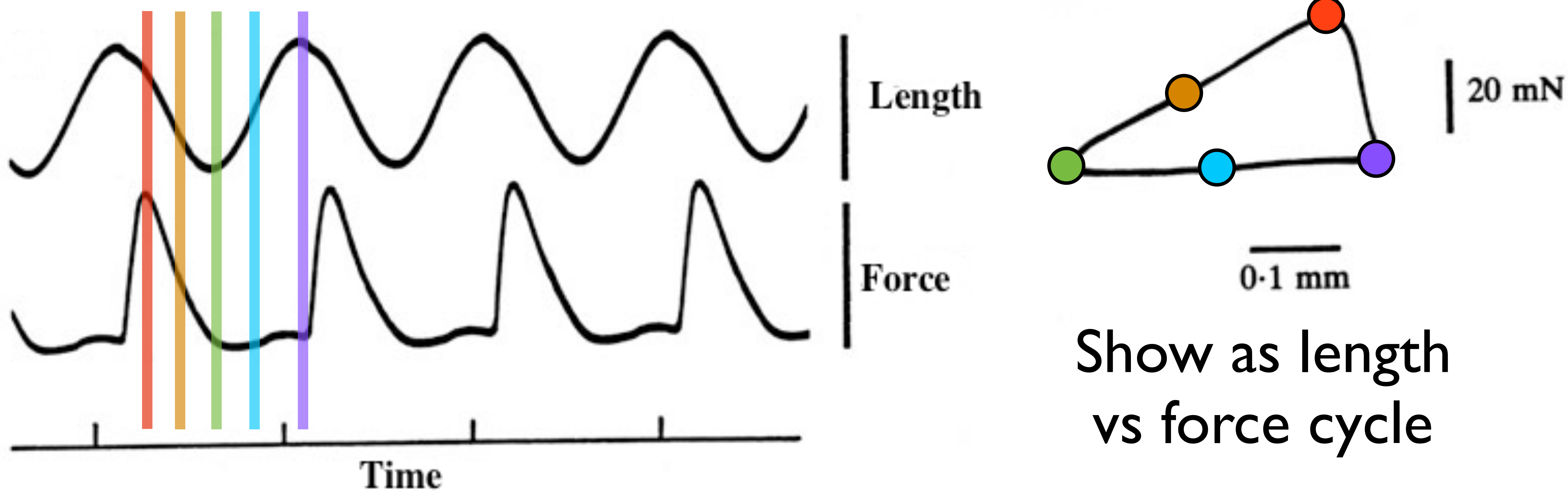
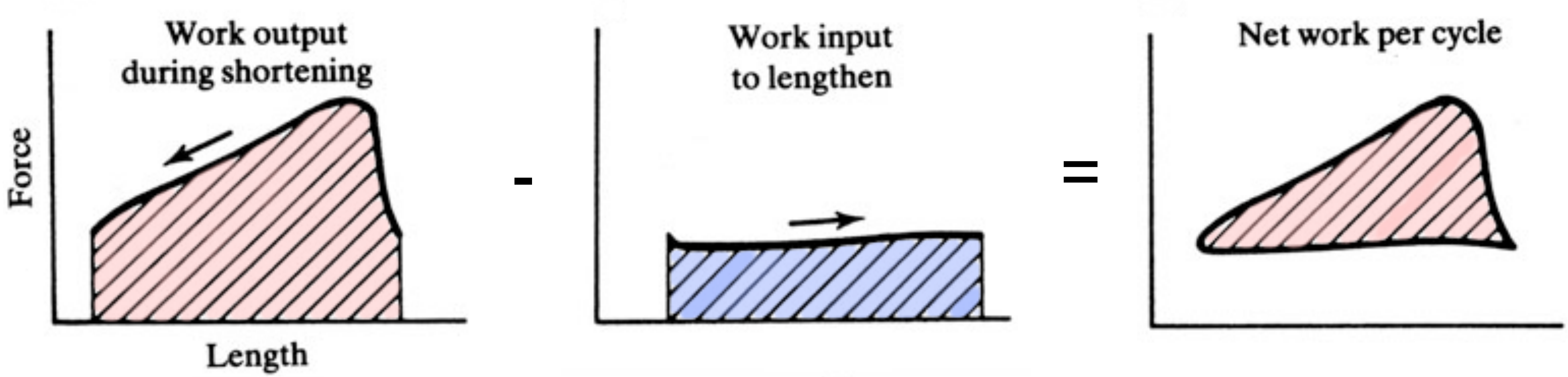


Plot the force as a function of length for one cycle of length change

Cyclical contractions - useful transform

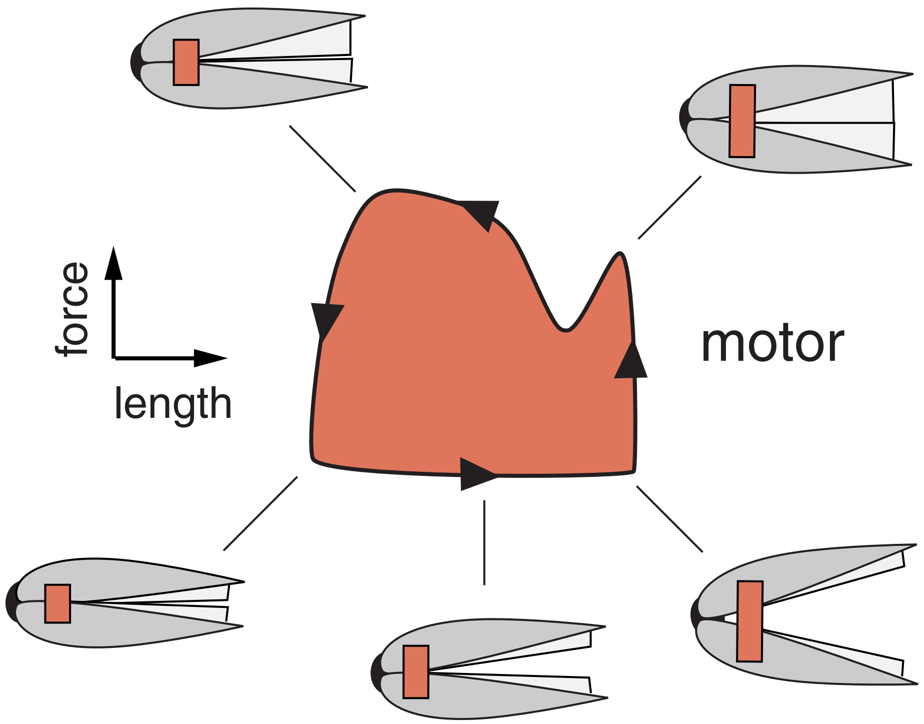


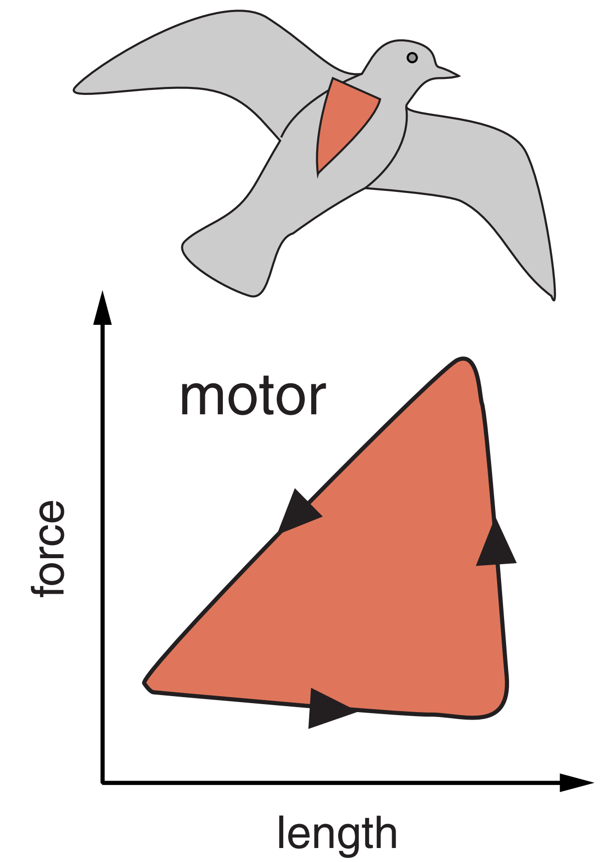
Show as length vs force cycle



Josephson, 1985

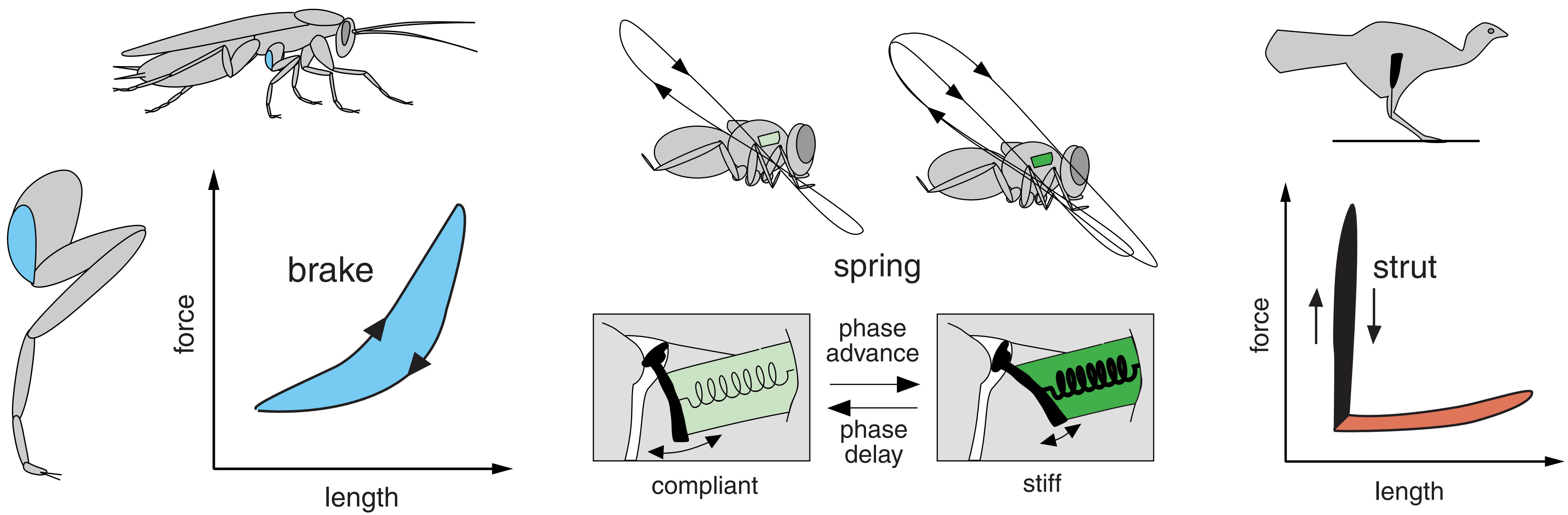
So we can see how muscle is a motor...





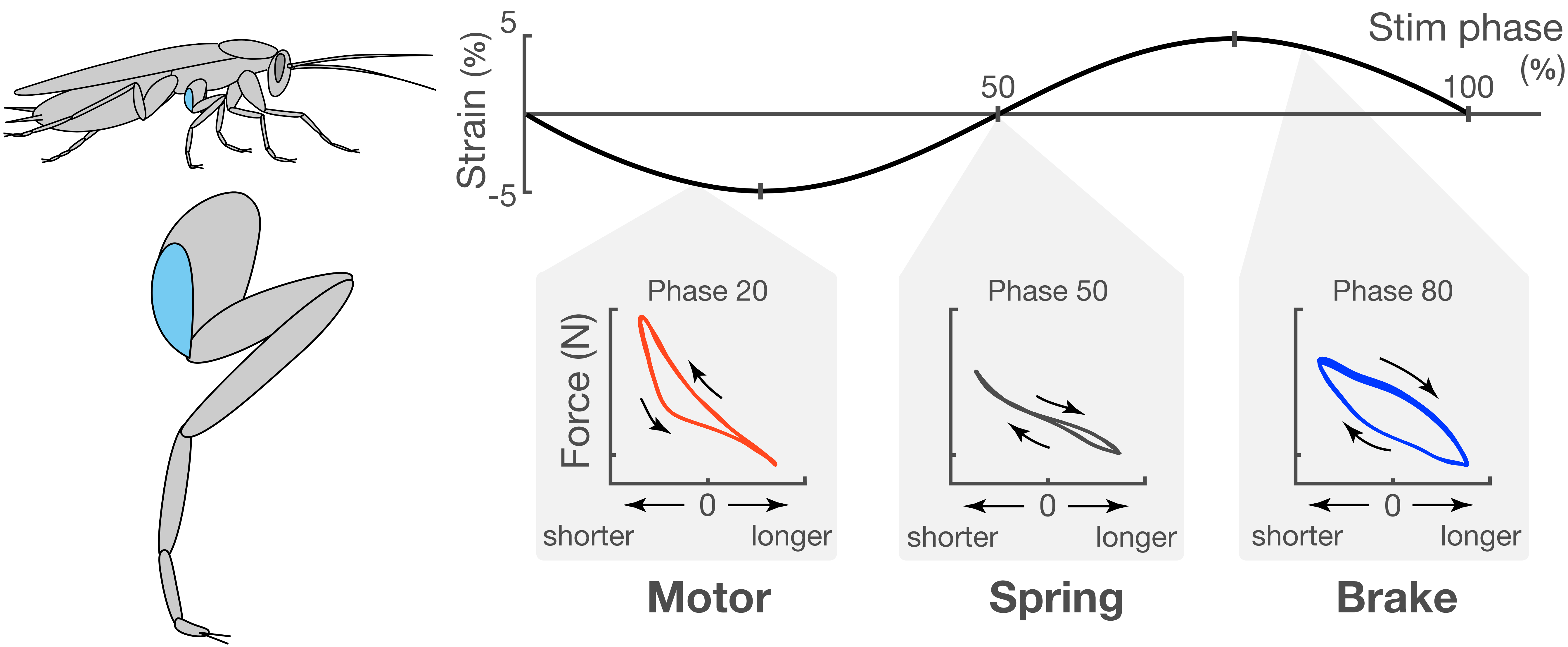
Dickinson et al, 2000, Science

... or a brake, spring, or strut

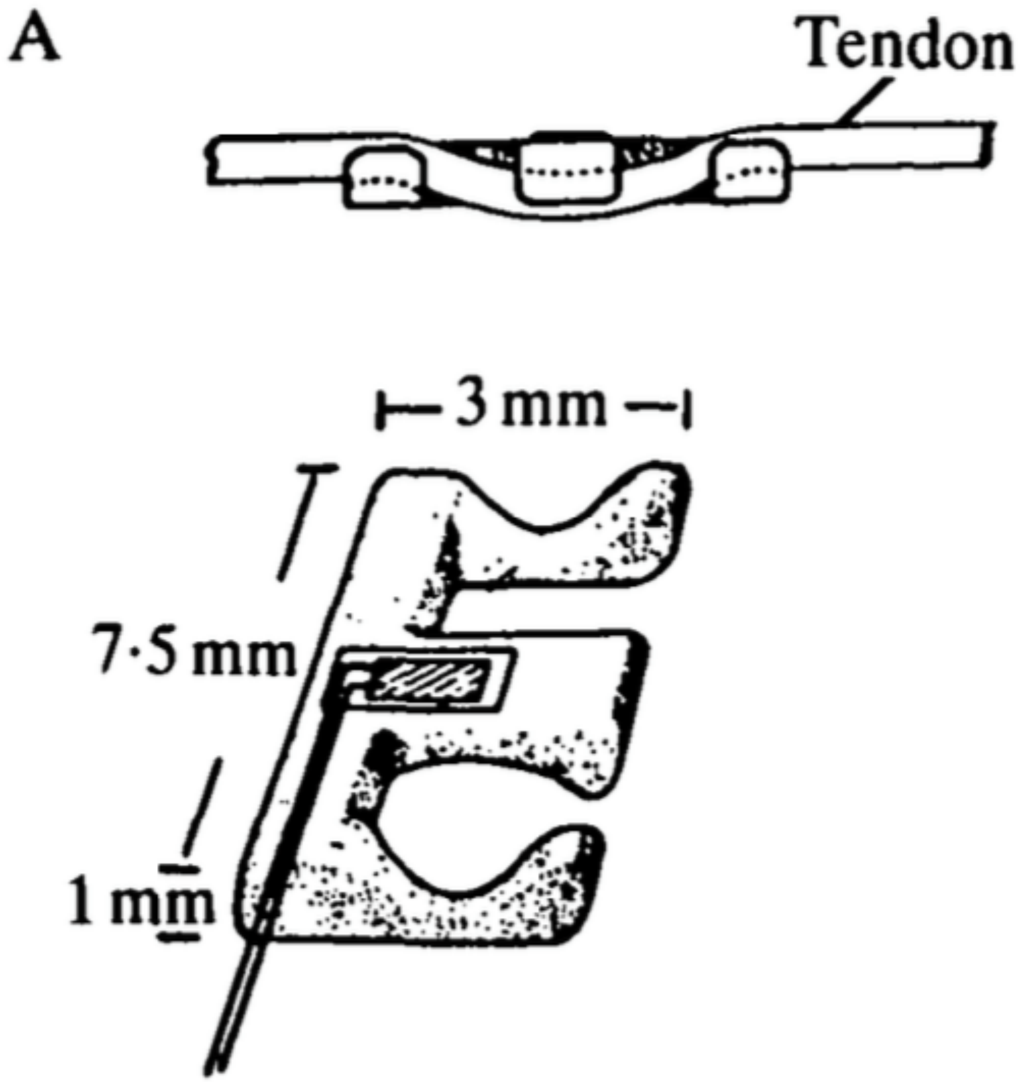


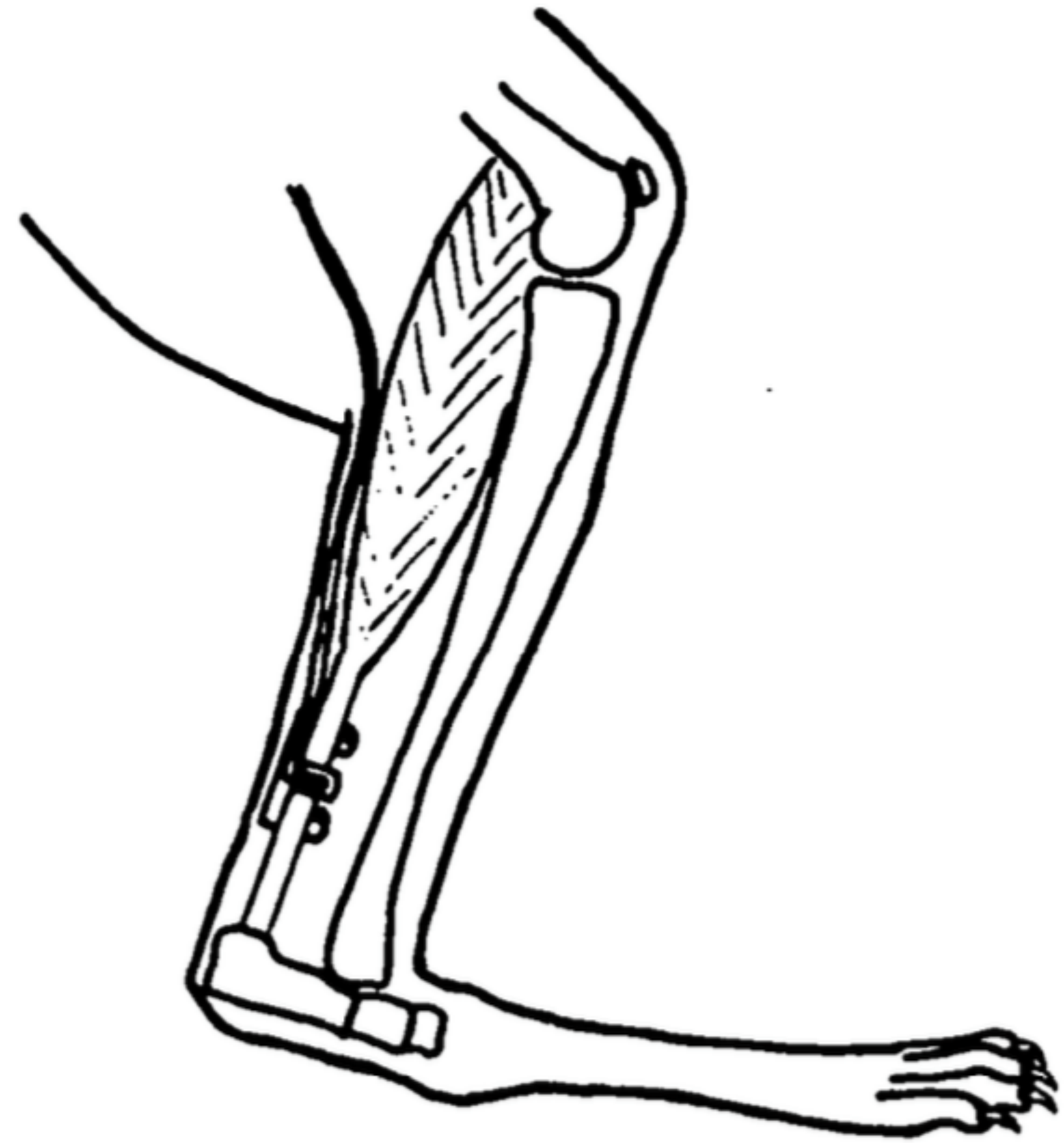
Dickinson et al, 2000, Science

Even a single muscle switches functions



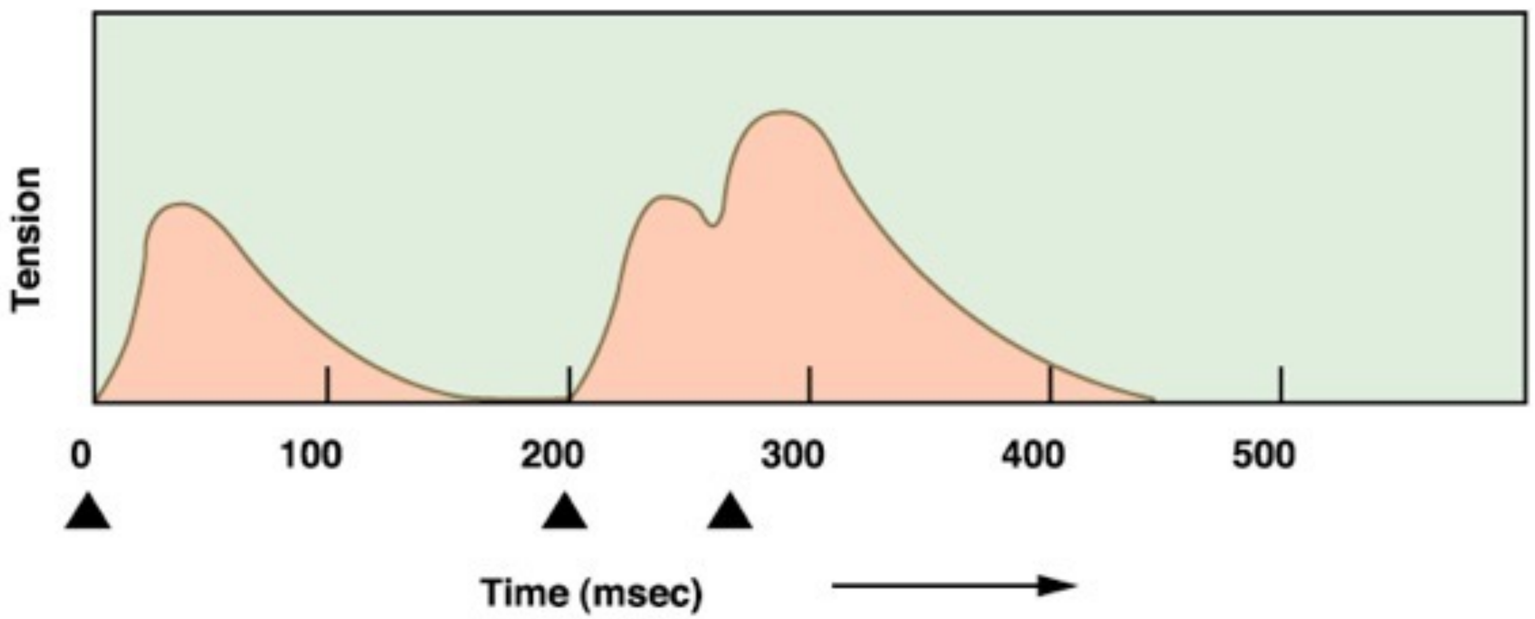
An aside, measuring muscle force *in vivo*



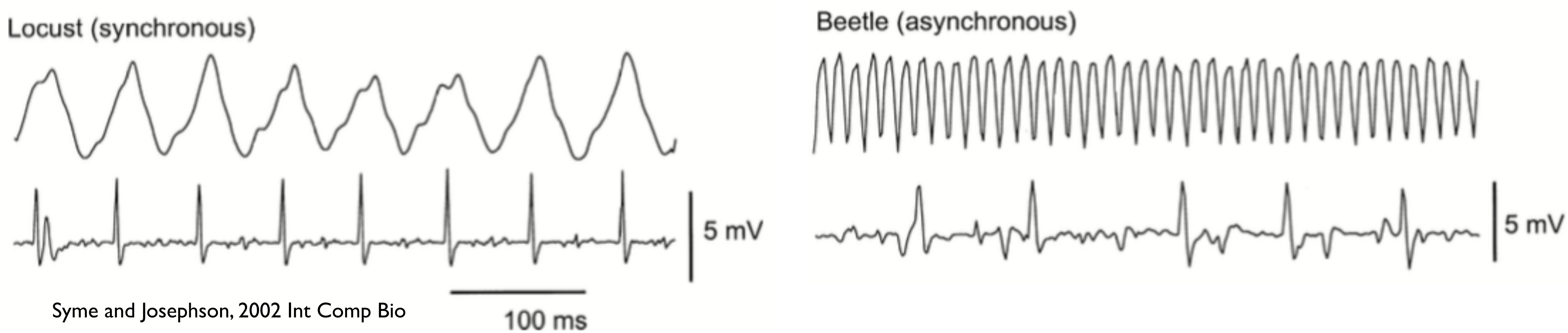


Biewener et al, 1988

Ca^{2+} pumping and diffusion limits



Impulses create twitches which can sum

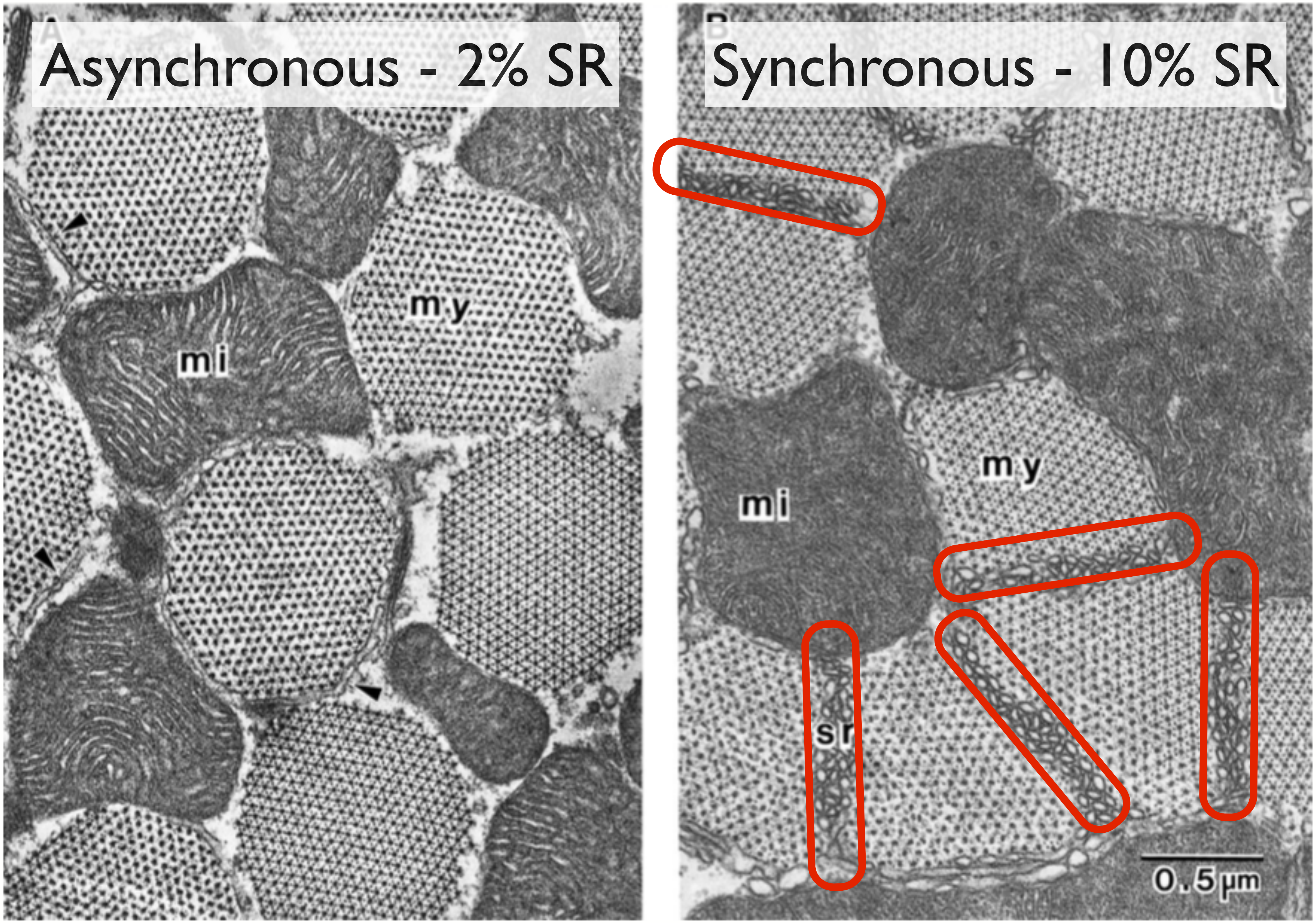


Syme and Josephson, 2002 Int Comp Bio

But pumping Ca2+ takes time, energy

Asynchronous muscle gets around that limit, but only near tuned frequencies

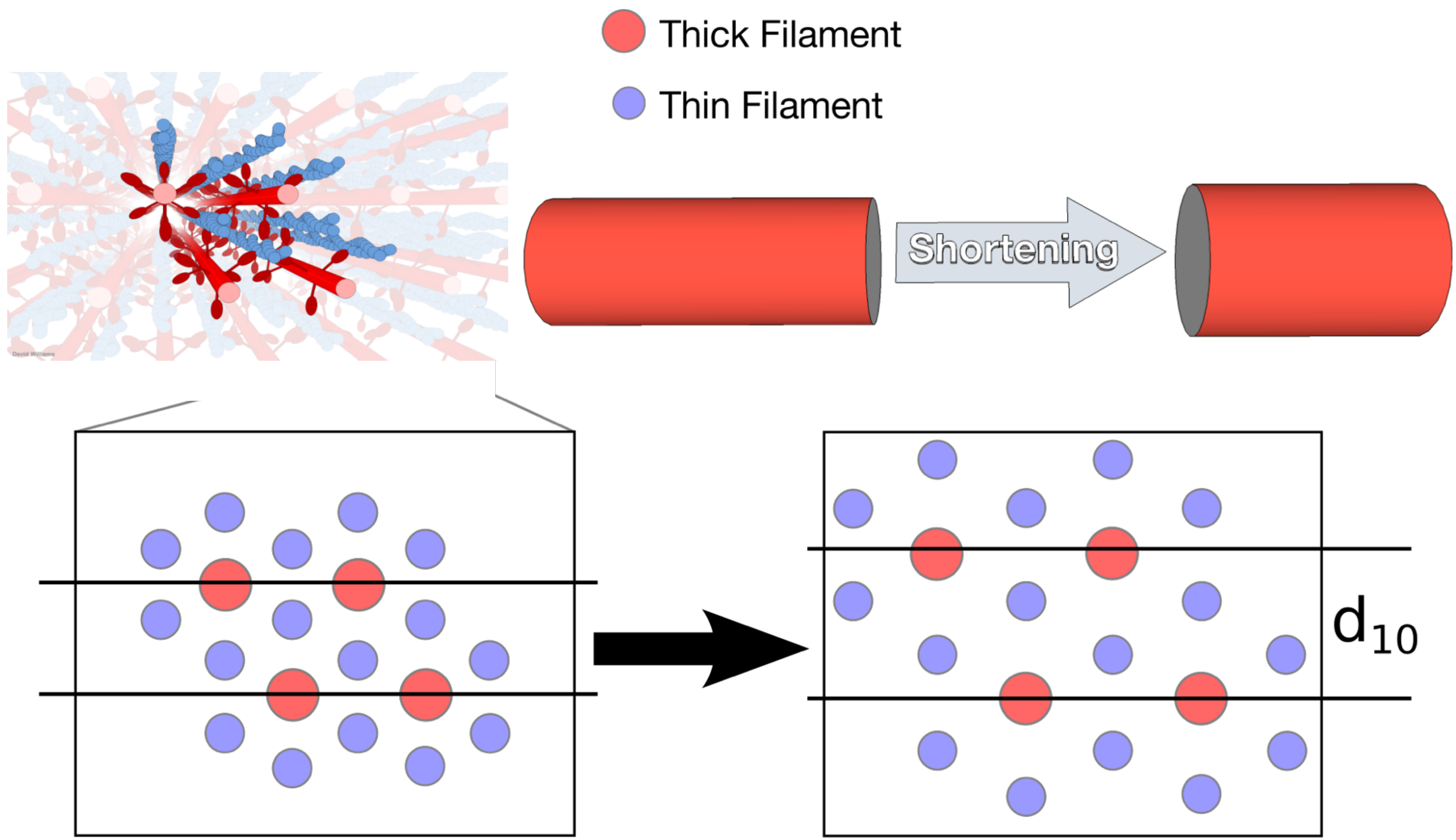
Asynch beats the SR limit on speed



Muscle cells are constant volume!

H: As muscle shortens, lattice spacing should increase (inversely with the square root of length).

Yes: Cross-bridges would need to reach a greater distance for actin binding? No: Fluid would move out of the lattice?



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Modular construction, and wide range of available subunits, permit tailor-made solutions to otherwise intractable mechanical problems

Choice of two control systems:

(1) Externally triggered mode. Versatile, general-purpose units. Digitally controlled by picojoule pulses. Despite low input energy level, very high signal-to-noise ratio. Energy amplification 10^6 approx. Mechanical characteristics: (1 cm modules) max. speed optional between 0.1 and 100 mm/sec. Stress generated: 2 to 5 x 10^5 N/m^2.

(2) Autonomous mode with integral oscillators. Especially suitable for pumping applications. Modules available with frequency and mechanical impedance appropriate for:

(a) Solids and slurries (0.01-1.0 Hz)

(b) Liquids (0.5-5 Hz): lifetime 2.6 x 10^9 operations (typical) 3.6 x 10^9 (maximum) independent of frequency

(c) Gasses (50-1,000 Hz)

Many options: e.g., built-in servo (length and velocity) where fine control is required. Direct piping of oxygen. Thermal generation, etc.

Good to eat.