Biology 427

1. Workloops. (6 pts) Consider a very idealized muscle exhibiting simple periodic length and force changes. It's length (l) changes as a simple sine wave and the force (F) it generates follows a cosine:

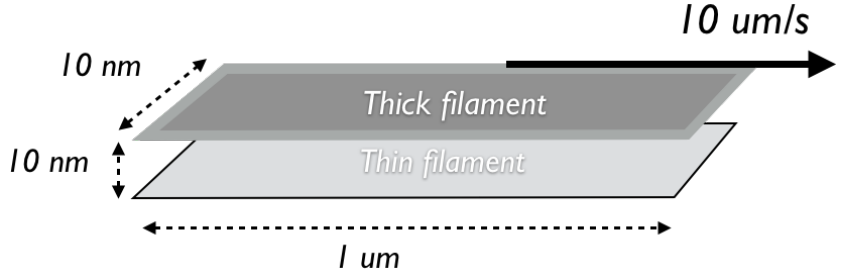
$l = 0.01 + 0.01 \cos(2\ pi\ f\ t)$ (l is in m)

$F = 0.01 + 0.01 \sin(2\ pi\ f\ t)$ (F is in N)

where f is the frequency of contraction and t is time.

a) Plot the workloop (force versus length) for this muscle.
b) What is the total work done by the muscle in one cycle?
c) Does this muscle act as a motor, a brake, or a spring? (explain your answer)
d) If the frequency of contraction (f) is 1 Hz, what is the power output of that muscle?
e) Under a different stimulation paradigm, the force generated by the muscle follows a cosine behavior: $F = 0.01 + 0.01 \cos(2\ pi\ f\ t)$. For this condition what is the work done by the muscle?
f) In this second stimulation paradigm does the muscle act like a motor, a brake or a spring? (explain your answer).

2. A thick filament is sliding past a thin filament (3 pts). For simplicity, each filament is assumed to be a long rectangular plate 1 μm long and 10 nm wide. The gap between the filaments is 10 nm. Further assume that the no-slip condition applies. (requires Monday's lecture).



(a) If the viscosity of cytoplasm is equal to that of water (0.0011 Pa s) and the filaments are sliding past each other at 10 μm/s, what is the shear force on either filament? (hint – what is the velocity gradient? What is the area over which the shear stress acts?)

(b) If a sarcomere consists of 1000 thin filaments in parallel, all moving identically, what is the total shear force on all of the thin filaments? (that is 500 thin filaments from one z-disk and 500 thin filaments for the other z-disk).

(c) What is the shear force (at equilibrium) exerted on all of the thick filaments between these two z-disks?

Aside: Recent literature suggests that cytoplasm viscosity can be more than 1000 times greater than the viscosity of water. But there are no data on the viscosity of the fluid within the filament lattice.

3. In this week's paper: "Fluid shear stress modulation of gene expression in endothelial cells" the authors examine how biomechanical factors can influence gene expression. The authors suggest that viscous shearing activates a membrane channel (or cytoskeletal components) and via indirect mechanisms activate gene expression. While the details of that transduction mechanism are not completely known, it is clear that shear stress can lead to gene activation.

The authors basically assume that the fluid viscosity is a fixed value. But, as you learned in class, the viscosity of fluids is temperature dependent. In your peripheral circulation (fingers, toes, etc) the temperature is much lower than in your core. What are the consequences of this temperature dependence to vascular endothelia?