MUSCLE AND BIOMECHANICS
HOMEWORK & STUDY QUESTIONS

MUSCLE MECHANICS

1a) Draw a graph (by hand, preferably) of the sarcomere length-tension curve of a muscle with the following filament dimensions: thick filament, 1.6 micrometers, bare zone 0.4 micrometers, thin filament, 1.1 micrometers. What is going on at the various portions of the graph? Label graph and describe with a sentence. (3pts)
b) In experiments on muscle, it is observed that contraction force drops off when the muscle is stretched beyond its optimum length. Why? Why does contraction force drop off when muscle is shorter than its optimum length? Why does muscle has an optimum length for most forceful contraction? (3pts.)

2) Describe the excitation contraction coupling (you may use a drawing, if you wish). How does contraction spread rapidly to all of the myofibrils? (3pts.)

4) You are eating a fish filet and notice some dark meat and some white meat. Which type of muscle can contract most rapidly? Which can generate more force? Which would be more resistant to fatigue (and why)? (3pts.)

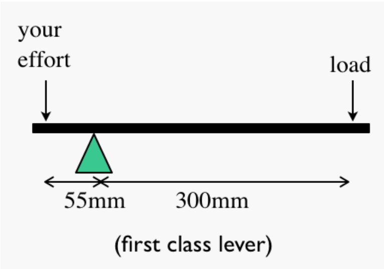
BIOMECHANICS & LEVERS

5) Levers are useful for amplifying force or distance of a movement.

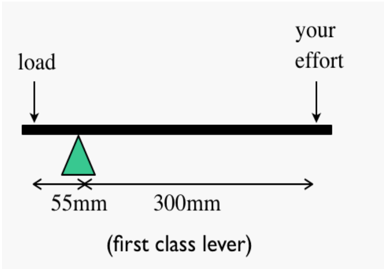
a. Show that you can calculate the force amplification from a ratio of the lever arms (hint: use the torque equation given in lecture). This is commonly called "mechanical advantage", but for our purposes we are going to call it "force advantage". Also give the equation for "distance advantage" (the reciprocal of force advantage). In your own words, explain what "force advantage" and "distance advantage" means to a locomoting animal. (2pts.)

Calculate the force advantage and distance advantage for the following lever systems: (2 pts. total for b-e)

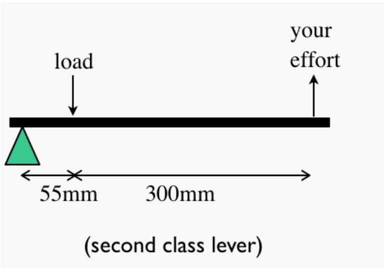
b.



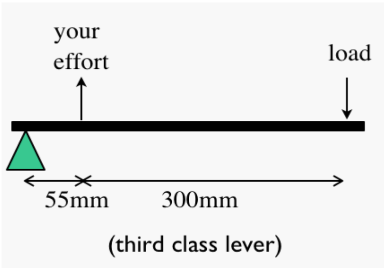
c.



d.



e.



f. Which of these levers best describes the attachment of the human biceps muscle at the elbow? Which the triceps? What would you predict about the mechanical behavior (force, speed) of the human arm about the elbow, and the roles of the biceps and triceps? Finally, muscles can only contract. So how can the biceps and triceps quickly return to their resting lengths after a big contraction? (2pts.)

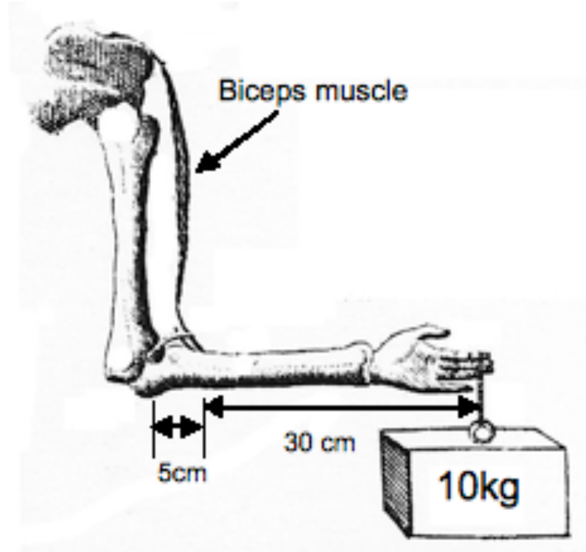
6) Keeping in mind what you learned from question (5): In class, you were given an example of a limb designed for speed (horse) versus one designed for power (the armadillo, a digger).

a. Assuming that effort ($Force_{in}$) is the same, describe how the difference in speed vs. power is achieved by comparing their force or distance advantages (qualitative, no numbers here). (1pt.)

b. Now think about muscle design: given the same volume of muscle, how you modify the muscle distribution to accentuate power vs speed? (1pt.)

c. Now think about the bones: do they have any differences in shape beyond length? Why would these differences be advantageous for their different behaviors? (2pts.)

7) For the following lever system (this is a third order lever the equation for turning force or torque given in lecture is the same in reference to in lever and out lever) :



a. If the muscle contracts at 5 cm/s, how fast will the weight be lifted? (1pt.)

b. The maximum isometric force that vertebrate striated muscle can produce is about 20 N/cm^2. The cross-sectional area of the biceps muscle above is about 20 cm^2 (note scale: CSA = πr^2) What is the greatest mass that this person can support against gravity? Is the above diagram reasonable? (3pts.)

c. Redesign the system to support the weight shown by increasing the CSA of the muscle. (2pts.)

d. Redesign the system to support the weight shown by moving the muscle insertion. (2pts.)