Torque and Levers

A) Objective: To examine the relationships and compromises between force output and velocity.

B) Preparation: Work in your seminar teams.

C) Discussion:

In the vertebrates, muscles generate forces and skeletal elements apply these forces. In this lab you will examine some simple biomechanical aspects of the mammalian forearm to gain a better understanding of the relationships between vertebrate form, function, and environmental demands.

There are several ways to represent this mechanically. Perhaps the most intuitive representation is with torques and levers. The balance of forces about a point of pivot (fulcrum) depends on the forces, multiplied by their lever arms (l_o or l_i), the perpendicular distance to this point of pivot. This product, force times lever arm, is termed a **moment**. One way to produce more output force is to move the point of pivot closer to the output force (F_2) and farther from the input force (F_1). To produce high output speed, the pivot point is moved closer to the input force.

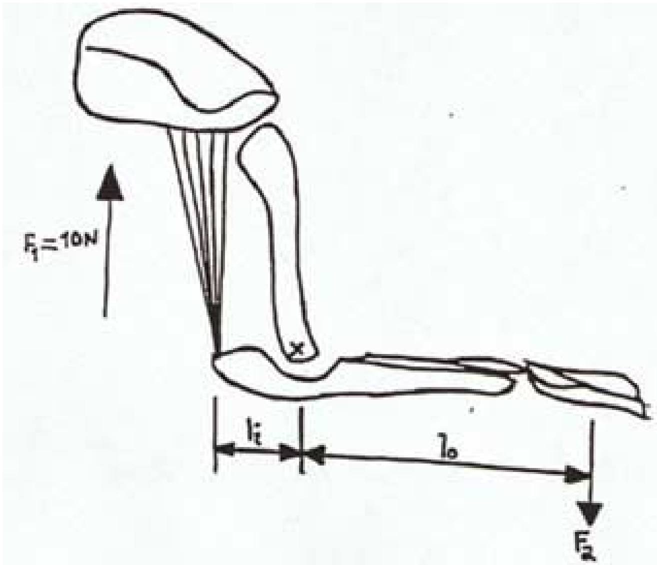
Exercise 1. Output Force

Determine the output force (F_2) delivered to the forefoot of representative mammals when the triceps brachii exerts a pull, input force, of 10 Newtons (F_1) at its insertion in the mammals listed on the data sheet. Recall that $F_1 l_i = F_2 l_o$ so that $F_2 = F_1 l_i / l_o$. Use rulers to measure the in-lever (l_i) and out-lever (l_o) in meters.

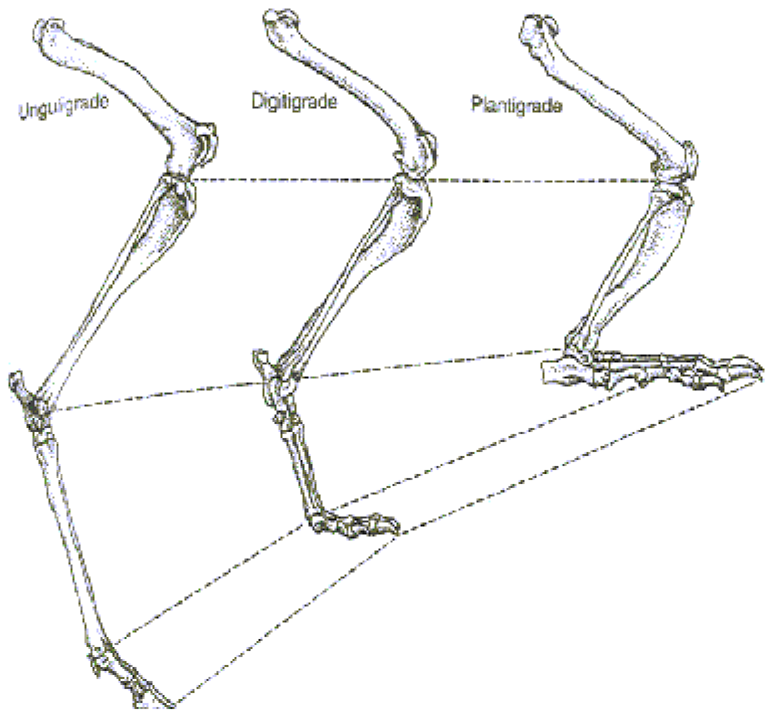
Specifically: **in-lever** (l_i) = distance very posterior tip of olecranon to center semilunar notch;
out-lever (l_o) = center semilunar notch to output site on foot.

Output site on the foot depends upon the foot posture, base of foot (plantigrade), midfoot (digitigrade), tip of foot (unguligrade).

Assume that the triceps brachii is at right angles to the olecranon process of the ulna. Also consider the scapula and humerus fixed. Use the calculator installed on the computers to make any necessary calculations.



F1 = 10N
li
lo
F2



Unguligrade
Digitigrade
Plantigrade

Exercise 2. Mechanical Advantage

Determine the mechanical advantage for each of the mammals. The ratio F_2/F_1 is called the **mechanical advantage**. But since $F_2 l_o = F_1 l_i$, one can determine the relative mechanical advantage (MA) without knowing anything about the forces: MA = $F_2/F_1 = l_i / l_o$. If the MA is less than 1.00, the foot will exert less force on the ground than the muscle is exerting on the olecranon process. If the MA is greater than 1.00, the foot will exert a greater force than the muscle.

Exercise 3. Velocity

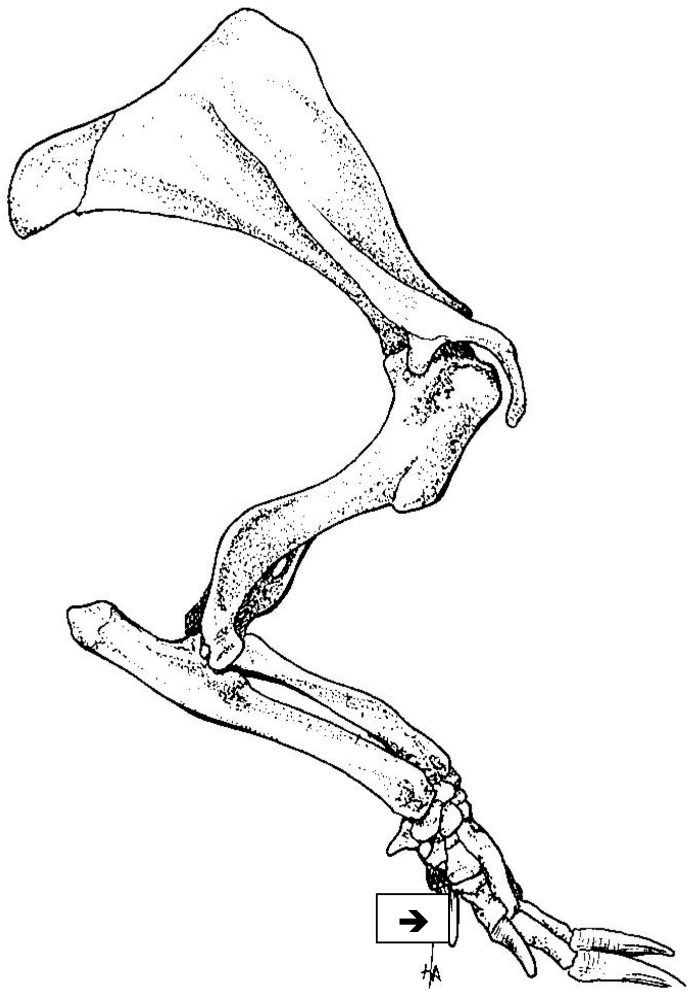
A second item of interest is how fast the foot moves with relation to the velocity of contraction of the muscle. This can be determined from the velocity ratio (VR). In a perfect machine without any friction, the **velocity ratio** = 1/MA.

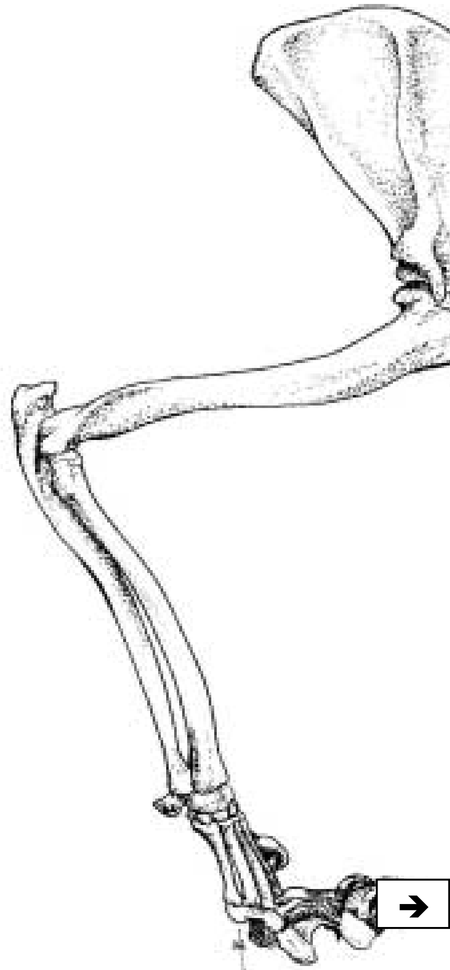
Using the data from exercises 1 and 2, calculate the actual velocity of the forefoot in each mammal if the muscle were to contract at a rate of 1/3 of its length per second. Assume that the length of the muscle is equal to the length of the humerus. To obtain the **actual velocity** in m/s, multiply VR by 1/3 the length of the humerus.

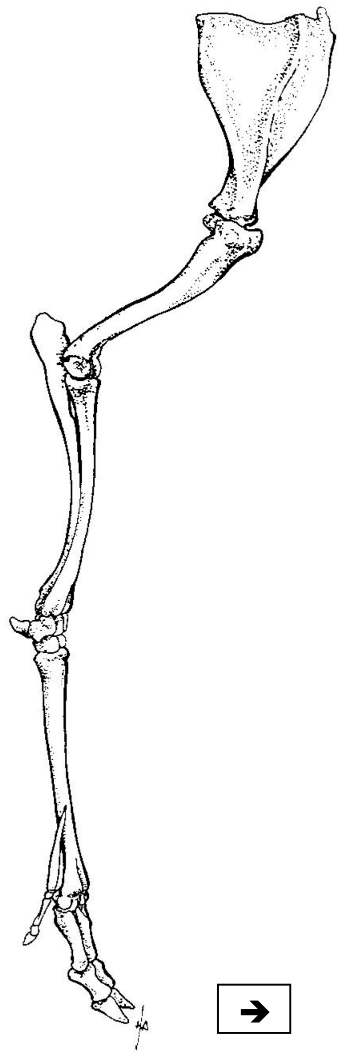
⇒Seminar Team Questions:

1. **What is the correlation between lifestyles of animals and their mechanical advantage and velocity ratios?**

2. **Would you expect a high mechanical advantage and velocity ratio in the same animal? Explain.**







Specimen	Foot posture	Humerus (meters)	l_i	l_o	F_2=F_1li/lo	Mech. Adv. l_i / l_o	Vel. Ratio 1 / MA	Actual Vel. VR x 1/3 humerus
Horse	Unguligrade							
Deer	Unguligrade							
Cat	Digitigrade							
Badger	Plantigrade							
Muskrat	Plantigrade							
Armadillo	Plantigrade							
Mole	Plantigrade							