These examples of bio-inspired robot configurations are only a small sample of the possibilities. Please use them for inspiration, but do not be constrained by them. Also note that I made several assumptions here to keep things simple.

1 Robot 1

Consider the robot shown in Figure 1, which shows a side view of the robot consisting of a body, arm, and tail. The robot's center of mass lies farther from the wall than the robot arm contact point on the peg (point B). The vertical distance from the tail contact point to the robot arm contact point is l. The horizontal distance from the center of mass to the robot arm contact point is d. The robot has a mass of m, and gravity, g, acts downward. Assume that the tail contact point is frictionless (it greatly simplifies the analysis). **Write the three static equations for this robot. For the moment equation, sum about point B, the arm contact point.**

The robot will stay on the pegs and wall if the reaction force, B_x, at the arm/peg interface is less than the friction force such that: $B_x < \mu B_y$ where μ is the coefficient of friction. Knowing this, along with the three static equilibrium equations you found above, **find a relationship between d, l, and μ.**

To improve stability, do you want d, l, and μ to be small or large? Think about this as you design your robot.

What happens if d becomes negative? In other words, the center of mass lies between the wall and the arm point of contact on the peg?

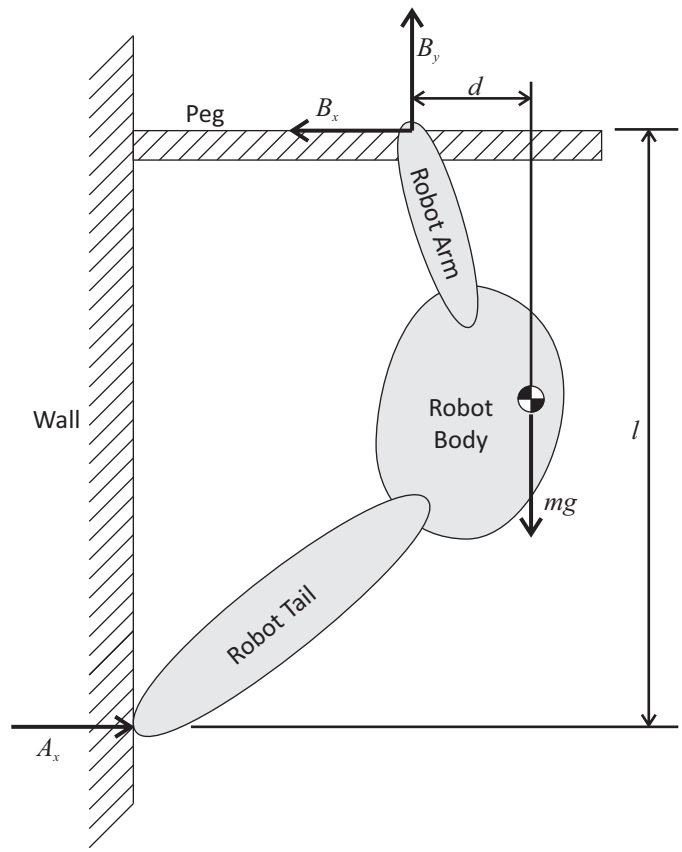

Figure 1: Robot example 1

2 Robot 2

Consider the robot shown in Figure 2, which shows the view as if you are looking directly at the face of the climbing wall. The robot consists of two rigid bodies, a main robot 'body' and a 'arm.' The robot crawls up the side of the pegs only; no part of the robot touches the wall itself. The vertical distance from the body contact point to the robot arm contact point is l. The horizontal distance from the center of mass to the robot arm contact point is d. The robot has a mass of m, and gravity, g, acts downward.

Knowing what you know from the first example, write down the relationship between d, l, and μ, the coefficient of friction between the arm and the peg.

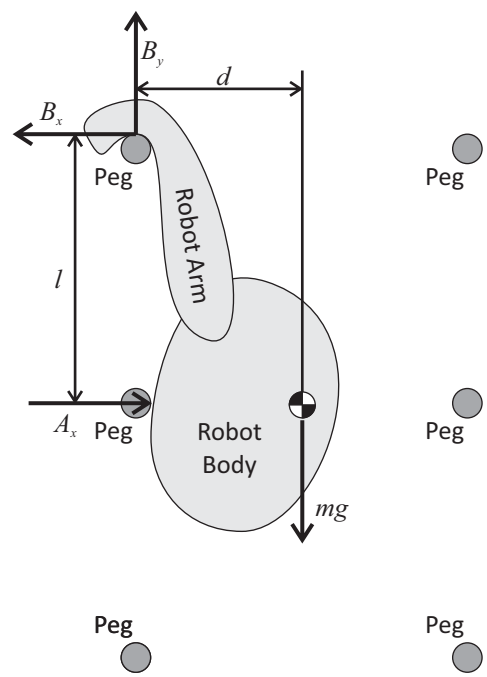

Figure 2: Robot example 2

3 Robot 3

Consider the robot shown in Figure 3. It uses two arms to pull itself up the pegs, so that one leg (as shown) needs to pull a load of $mg/2$. For this type of robot, the leg needs to be able to lift the robot. Given that the torque on the Hitec Servos that we use is 320 mN m and the length of the leg is l, **find the relationship between the mass, torque, leg length, and angle θ** by summing the moments about the servo joint.

Using Matlab or Python, **plot the mass as a function of l and θ.**

Do you want l to be large or small?

Qualitatively, what happens to your robot if you make l really large?

Qualitatively, what happens to your robot if you make l really small?

What is maximum mass you can make your robot?

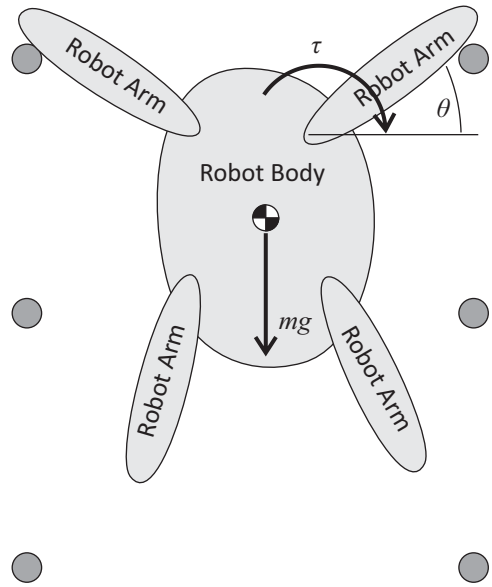

Figure 3: Robot example 3

A factor of safety is a multiplier that is essentially a 'fudge factor' in your designs. For example, if you calculated the maximum mass to be 1 kg and you have a factor of safety of 1.1, you would try to build a robot with a mass less than 1/1.1 =0.91 kg. This would account for mistakes made in your assumptions or inaccuracies in the torque measurements for the servo. **What do you think would be a reasonable factor of safety for your robot?**

4 Robot 4

Consider the robot shown in Figure 4, which consists of three rigid links. The outer two links serve as arms, and the middle link serves at the body. One servo sits at each of the two joints between the links, exerting torque τ_1 and τ_2, respectively. The middle link has mass m_1. The right link has mass m_2. The length of the middle link is l_1. The center of mass of the middle link lies l_{c1} from the left joint. The length of the right link is l_2. The center of mass of the right link lies l_{c2} from the right joint. The angle between the horizontal and the middle link is θ_1. The angle between the middle link and right link is θ_2.

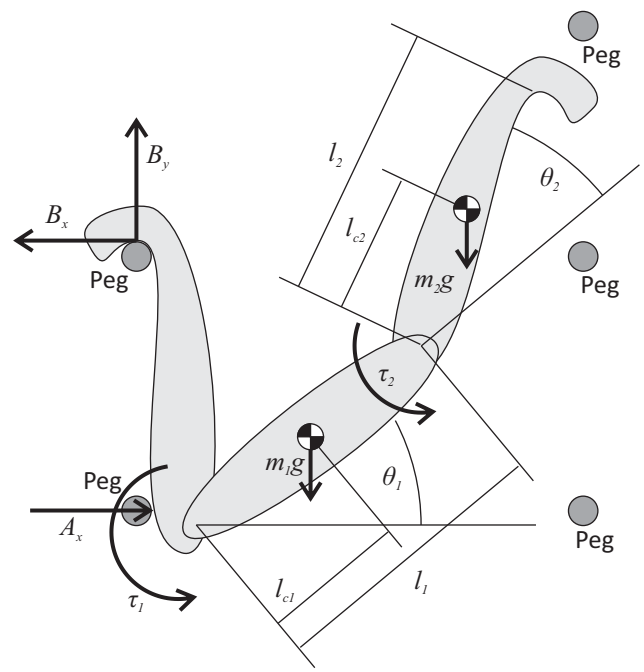

Figure 4: Robot example 4

We are concerned on whether or not the servos have enough torque to raise the arms. **Which servo (associated to τ_1 or τ_2) needs higher torque as the robot is drawn here?**

Solve for the required torque of that servo by summing the moments about that joint.

Based on that equation, what are the angles, θ_1 and θ_2, that maximize the required torque?

To make things easier, assume that the masses are the same ($m_1 = m_2$) and solve for m.

Knowing that the horizontal distance between the pegs is 152 mm, the vertical distance is 102 mm, assume that the $l_1 = l_2 = 110$ so that the arm is long enough to reach the next peg and that the center of mass lies in the middle of the robot arms ($l_{c1} = 0.5l_1, l_{c2} = 0.5l_2$). **Compute the maximum mass of each of the robot arms** knowing that the servo torque is 320 N mm