WEEK 1

Article: Wang *et.al.*, Insect-scale jumping robots enabled by a dynamic buckling cascade, *PNAS*, 2023.

QUESTIONS (Group 1b)

1. The mathematical modeling section uses a simplified lumped mass-spring model to predict the jumping height and velocity of the robots, noting a good agreement between theory and experiment. However, the model breaks down somewhat towards the end of each jump, with the predicted velocity leveling off while the experimentally observed velocity does not. In what ways could the mathematical model be refined or expanded to more accurately capture the complex dynamics of the jumping robot, particularly concerning the ground interaction and energy dissipation during the later stages of the jump?

2. The Sy robot achieves consecutive jumping due to an additional top beam that provides a restoring force, allowing the artificial muscles and the robot body to return to their original length after the first snap-through. This mechanism enables a second jump, though the robot must be manually righted before it can do so. Given this setup, what are the limitations that prevent a third jump from occurring? Is the restriction due to material fatigue, insufficient restoring force from the top beam after multiple cycles, or another factor?

3. Why is increasing the restriction height (h_R) leading to a higher takeoff velocity but eventually reaching a plateau? Could a fully unconfined snap lose efficiency if the beam does not impact the ground at all? Figure 6D shows the acceleration of the system with respect to h_R. What would happen if we had a higher h_R? Would it be possible to find an optimal value to maximize the acceleration of the system? The duration of positive acceleration increases with increasing h_R. The theoretical limit is h_0 (midpoint of the buckled beam). However, they found that trying to set h_R as close as possible to h_0 is not optimal either. Why?

4. Is the "body length L" accurate in order to determine the energy density and escape time of the jumping system in insects? For the Sy robot, resetting its muscles to their original shape for a consecutive jump takes approximately 200 seconds, whereas click beetles can reset themselves within a few seconds. What causes this two-order-of-magnitude difference between the natural system and the robot? Could this gap be reduced by optimizing the current design? If not, what is the limiting factor?

5. The elastic energy storage is performed through beam buckling. By using a beam with bigger dimensions, one can store more elastic energy during the buckling process, resulting in an increase of jump height but also to an increase of embedded mass, which is penalizing for the jump height. Therefore, what is the optimum in terms of beam dimensioning to maximize the jump height? How would the performance and escape time of the dynamic buckling cascade robot vary if its scale were further reduced, given that lambda represents the size ratio (lambda<1 as the model shrinks), with stiffness scaling as lambda and volume (and therefore mass) scaling as lambda^3?

6. The researchers chose coiled artificial muscles as actuators. What properties of these actuators make them particularly suitable for the rapid energy storage and release required for jumping? Why are mandrel-coiled muscles better suited for a jumping robot using dynamic buckling cascade as presented in the article? Changes on the order of millimeters in the restriction height can change the acceleration at the onset of phase 3. Do you think having a temperature driven actuation impacts the jumping performance of the robots, or are the deformations induced negligible?