

Dynamic Models in Biology

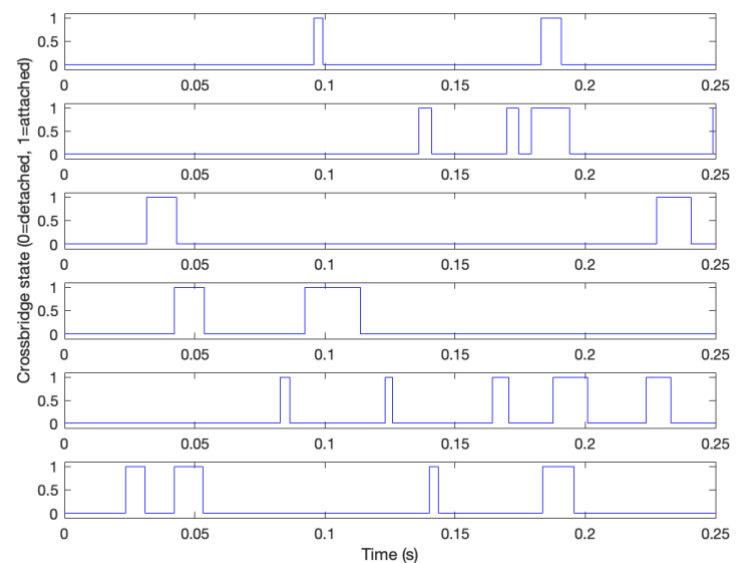
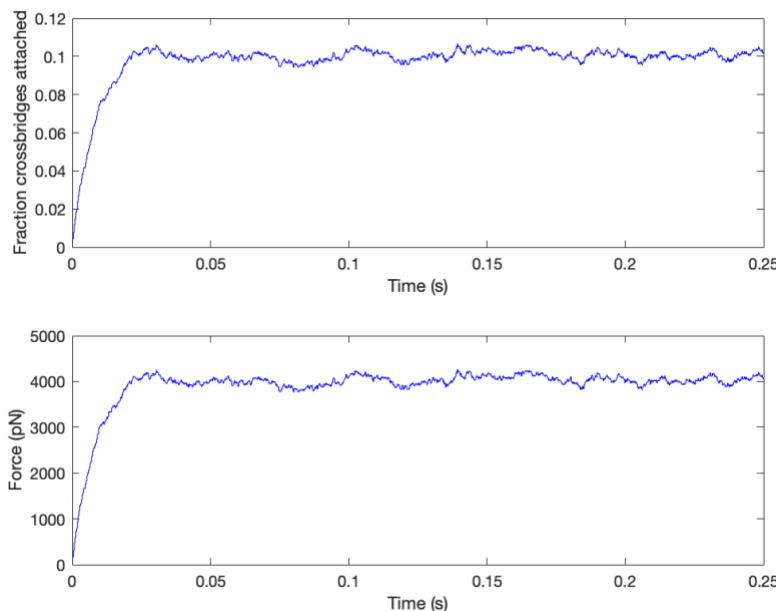
Lab 9

Jonathan Levine

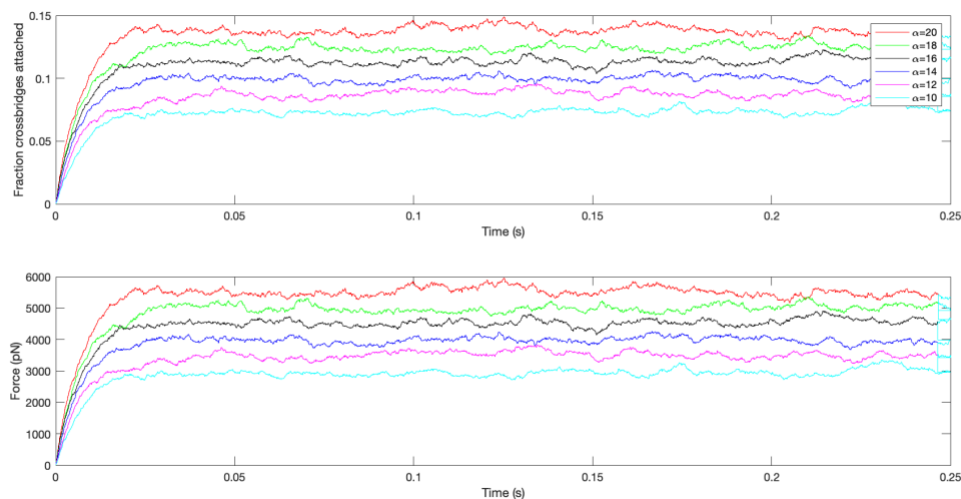
Fall 2023

Baseline Run

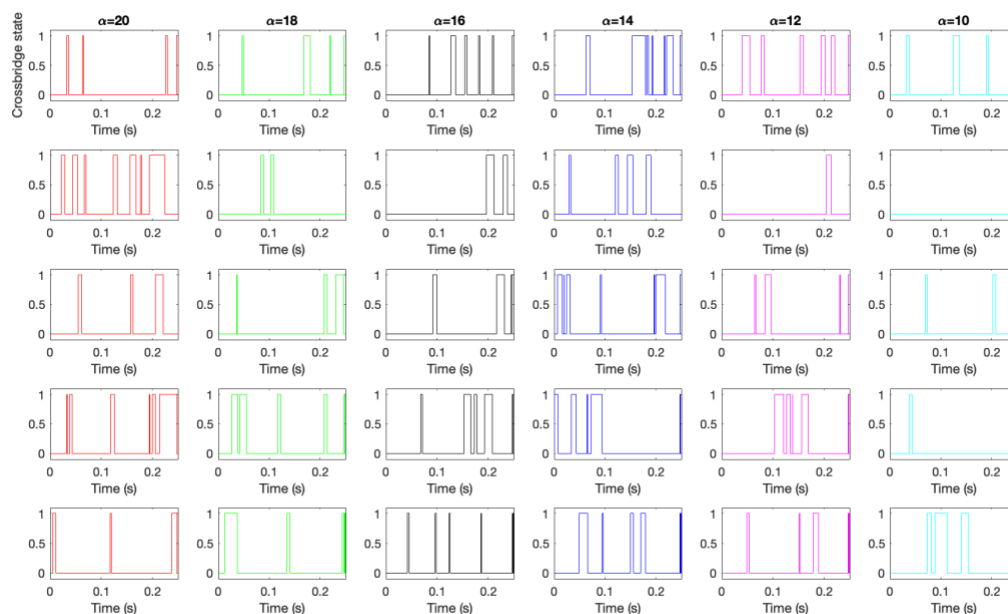
The baseline run is shown below. A sample of 6 of the N crossbridges are shown in the figure on the right, as they stochastically attach/detach over time based on the rates α and β . The full model of all N are shown on the left, where you can see the noisy curve generated by the underlying stochasticity of each individual crossbridge. The force is just the sum of the individual forces for each individual crossbridge.



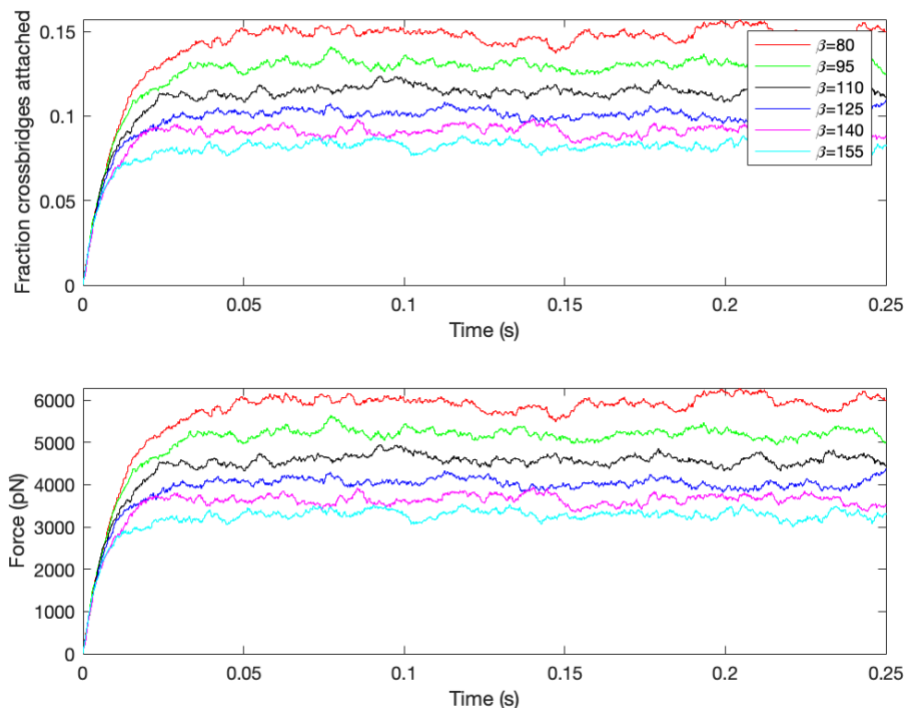
Varying α , we can see that the fraction of crossbridges attached over time increases as α increases, which also leads to a larger total force. This is because the attachment propensity is increasing, which translates to more attached at any point in time.



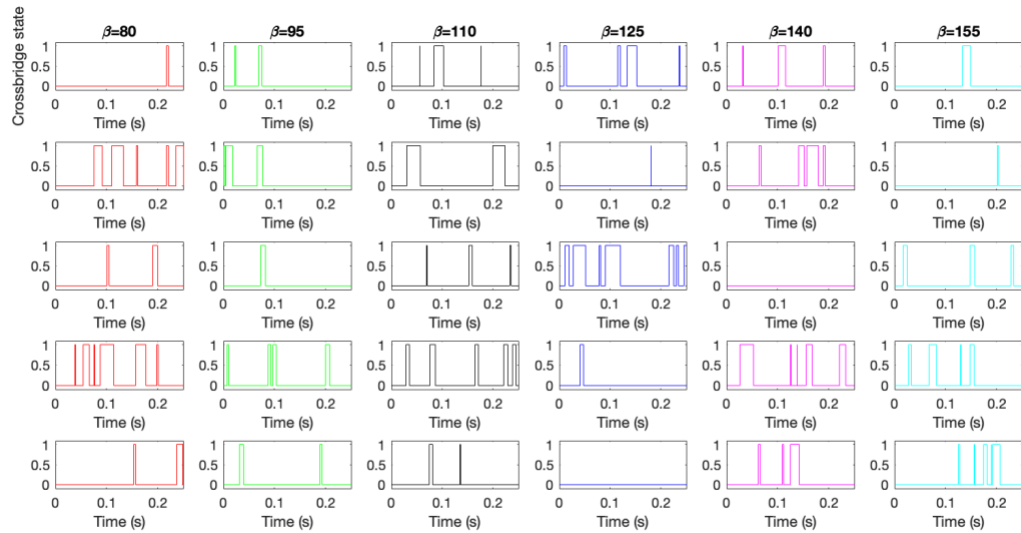
In terms of individual crossbridges, it is slightly harder to see the pattern as it is very noisy, but on average it does seem that openings happen more quickly as alpha increases (as you move from right to left in each row). The average effect is much stronger than the individual effect which is a lot noisier and random. (Each cell is an individual crossbridge, each color-coded column is 5 sample cells from one simulation run with the indicated value of alpha for that simulation).



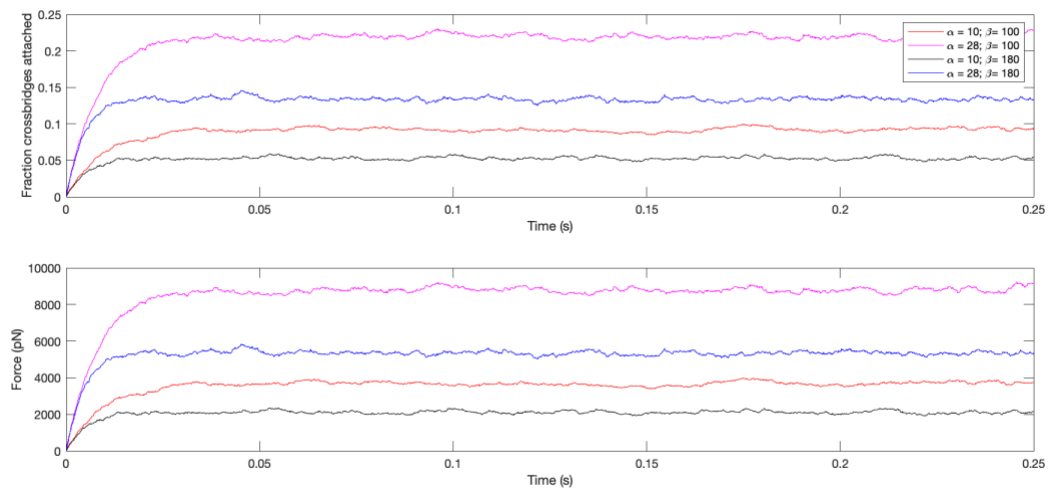
Similarly, if we vary the detachment propensity, beta, we again see the clear cumulative effect on the % open and force, this time in the opposite direction:



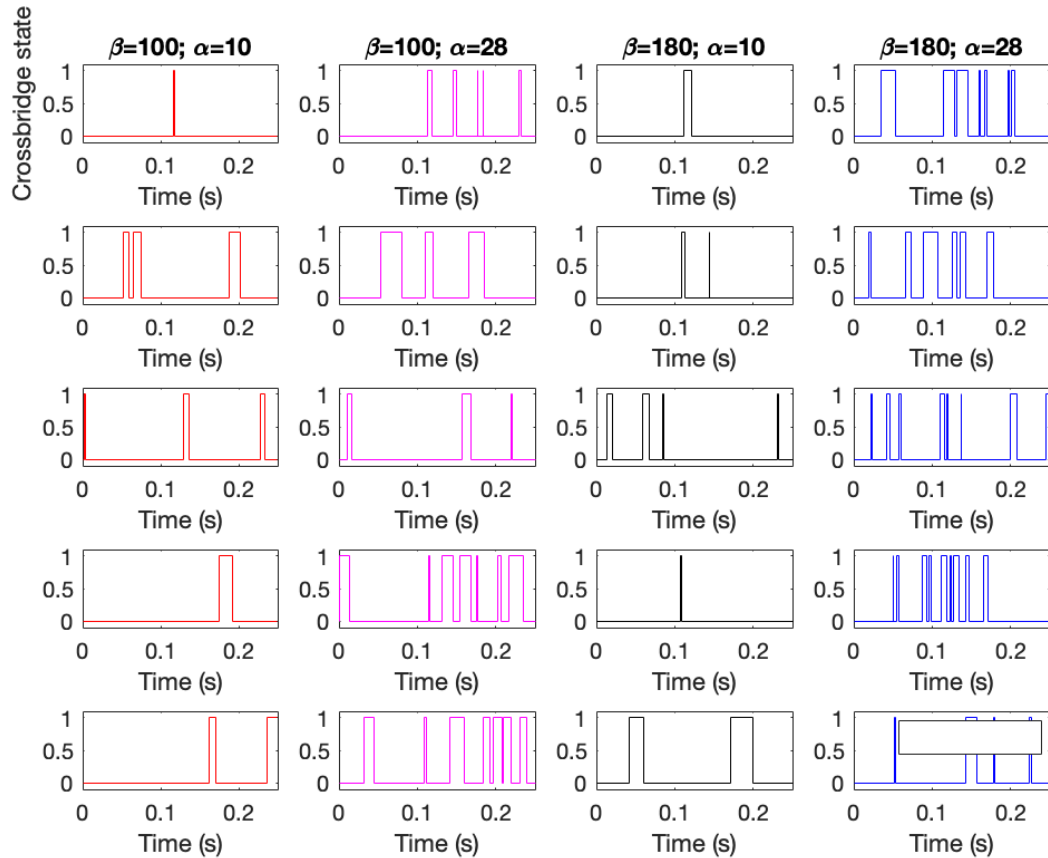
Again, this effect is not readily apparent from the individual crossbridges, which maybe you can see have faster closing times as beta increases, but is hard to tell from the individual dynamics:



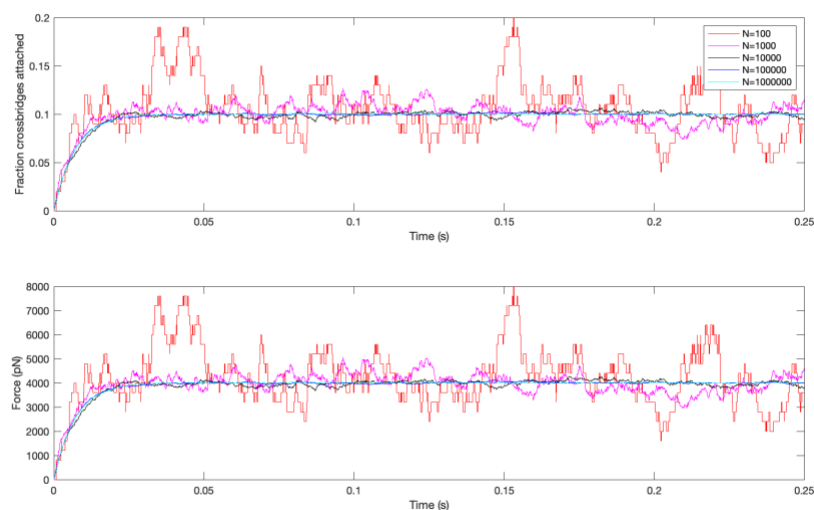
Varying alpha and beta simultaneously, we can see that increasing alpha and decreasing beta maximizes the probability and force (pink), while decreasing alpha and increasing beta minimizes it (black). Thus as expected, the fraction of attached bridges and the resulting force depend on and are sensitive to both alpha and beta.



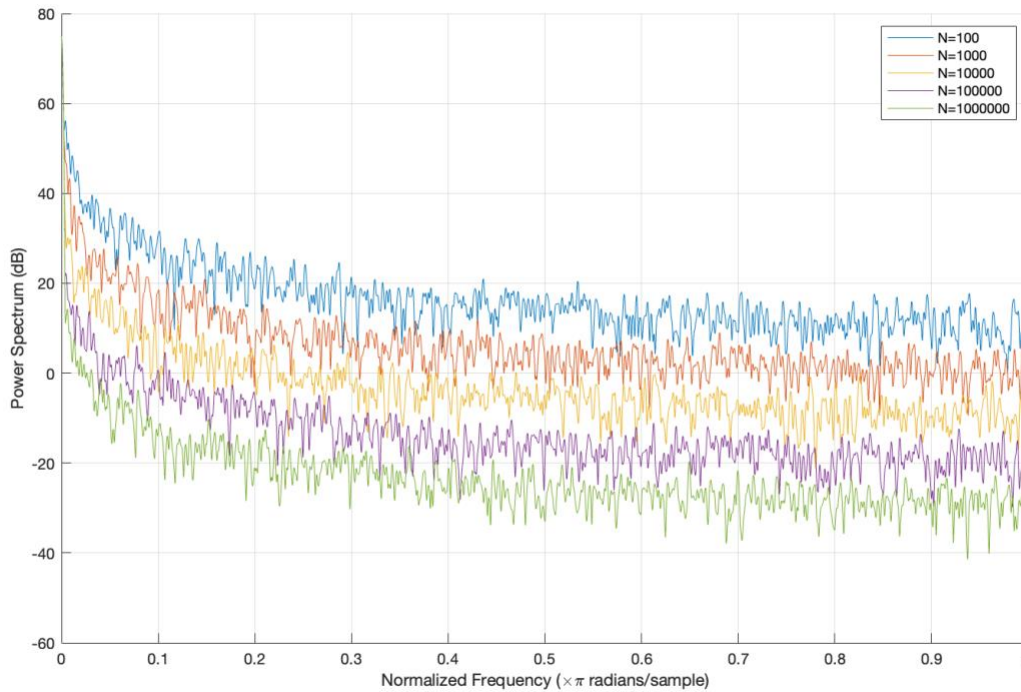
In the individual 5 samples, it is again hard to see the cumulative dynamics due to the noise, but there are clearly some differences between the conditions that appear even at this level. For example, the pink trace clearly has a lot of sustained openings since alpha is high and beta is low, while the black trace has few sustained openings since alpha is low and beta is high:



Using the baseline alpha and beta values, we can also vary the number of individual crossbridges and see how the number affects the noise levels of the cumulative curves. You can see that the noise decreases as N increases, with the low number regimes being really noisy (red or magenta) and the high number regimes being almost noise-less (blue or cyan)

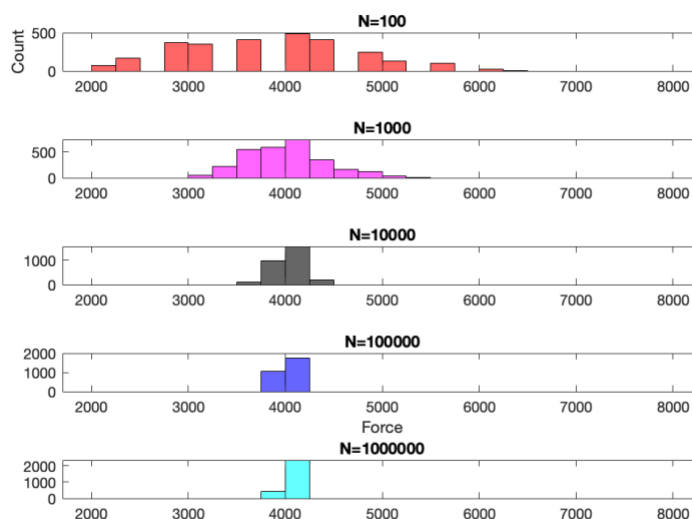


You can also visualize this noise as oscillations in the high frequency domain, visualizable in a power spectrum plot after running a FFT on the time series:



You can clearly see the power in the higher frequencies decrease as a function of the number of crossbridges used in the simulation.

You can also visualize the decrease in noise by looking at the distribution of force values after the steady state is reached (here I chose after $t=0.05$). You can see that as N increases, the distribution gets tighter with a lower variance:



Mathematically, this dispersion/tightness can be captured using the coefficient of variation (std/mean). Adding a few more N values to get a smoother curve, you can see the COV scales with $1/N$:

