Last Homework

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Ari worked on Myosin Simulation Race! Jose worked on the Cytoplasmic Streaming in drosophila oocytes problem. Eric worked on Effect of charges in solution.

1 Cytoplasmic Streaming in drosophila oocytes

1.1 What happens when certain parameters change?

The number of beads is set to n=48. By increasing the number of beads to a larger integer, the model becomes slower. f_{kin} is the Kinesin constant which will measure of how much force the chains is applying tangent to the direction of the microtubule. When the program is running, the microtubule will rotate clockwise. If the Kinesin constant is changed to a negative value, then the microtubule will change direction and rotate counterclockwise. When we changed the Kinesin constant to a negative value, the Kinesin changes direction and starts moving upwards. StiffnessConst is set to 10.0. This constant is an elastic constant of the microtubule. When the StiffnessConst is set to 20.0, the microtubule has to rotate slower. This is due to the increase of work needed to make the microtubule move. The force due to an external velocity field, f_{const}, is set to 0.4. This value was increased to 1, then to 10. As the f_{const} increases, the microtubule straightens.

1.2 Radius of Curvature

$$Radius\ of\ Curvature = (\frac{StiffnessConst}{f_{kin}})^{\frac{1}{3}} \tag{1}$$

The radius of curvature will have the dimension of length. In the program, the graphics where changed from True to "graphics = False". The external force field $f\_const[1]$ was set to zero with StiffnessConst = 10. Based on the programs output, the radius of curvature when StiffnessConst is 10 results with a value of 0.217. Last, StiffnessConst was changed from 10 to 20. The radius of curvature when StiffnessConst is 20 results with a value of 0.171. When StiffnessConst is doubled, the result will deviate by a factor of cubed root of two. So, if we multiple the value 0.171 by a cubed root of two, then we will get the radius of curvature when StiffnessConst is 10.

The graphics are set back to True. A wall force is added, and $f\_const[1]$ is set to 0, 0.3 and 0.9. The wall force prevents the microtubule from penetrating a wall located at the plane x = -1

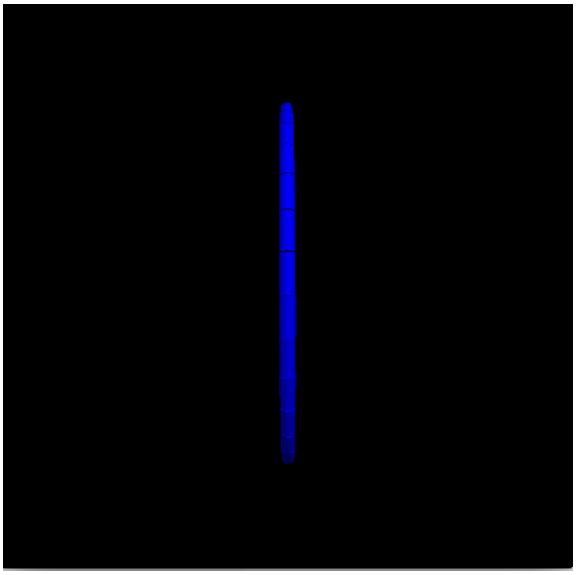

Figure 1: When $f\_const[1] = 0$

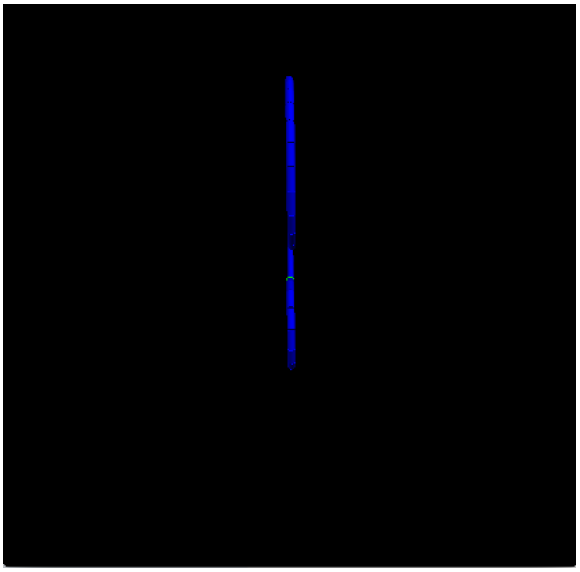

Figure 2: When $f\_const[1] = 0.3$

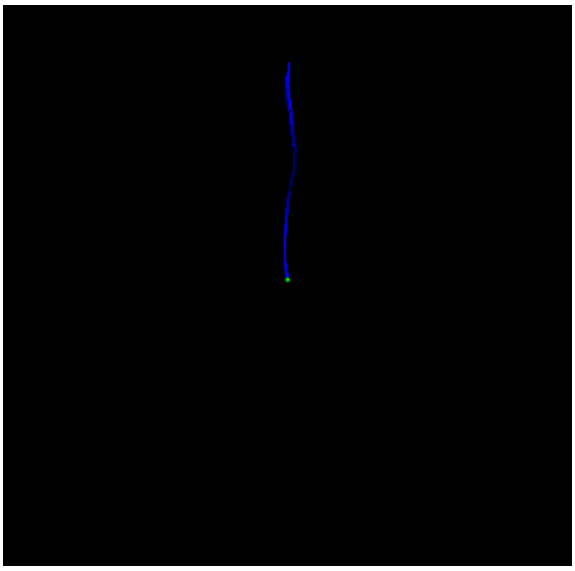

Figure 3: When $f\_const[1] = 0.9$

As seen in Figure 3, the microtubule is shaped as a sinosoidal. While in Figures 1 and 2, they are the least unraveled. As $f\_const[1]$ increases, the microtubule unravels and seems to push trough the cytoplasm faster.

1.3 Biology

The experiment was recorded by time-lapse microscopy and analyzed by digital tracking. The partial inhibition of kinesin-1 severely reduced fast streaming. Dynein, a motor protein, is really important. Without Dynein, the oocyte will stop development. Surprisingly, after adding inhibitory antibodies specific for dynein, made the oocytes prematurely show fast cytoplasmic streaming.

The main focus was the movement of the cytoplasm of a large eukaryotic cell from a Drosophilia oocyte. Cytoplasm contains both small and large particles. The movement of small particles is due to diffusion, but large particles do not diffuse well. This is why the cell has developed a way that will move these large particles.

Just like in a city, there are roads in a cell known as microtubules. Microtubules are made out of a maller subunits, Tubulin. Kinesin-1 is the vehicle that transports the large particle on this microtubule road. The direction of transport is unidirectional, so what determines the direction? Based on Mallik and Gross, the transportation is bias due to the direction the covalent bond of the Kinesin-1 is facing where ATP will couple and dispatch movement.

There are two main forms of movement slow and fast. One experiment that Serbus et al did was to inhibit the motor protein dynein before the fast streaming stage with inhibitory antibodies[1]. Actin cytoskeleton was also inhibited. When

the strength of actin cytoskeleton was loosened or inhibited, we see premature fast streaming, too.

Serbus et al determined that Kinesin was necessary for fast streaming, but it is repressed by dynein and actin cytoskeleton[1]. In order to determine if premature fast streaming is dependent on kinesin, inhibitory anti-Khc antibody was injected into the oocytes. The kinesin was repressed and so was the premature fast streaming.

1.4 References

[1] Serbus, Laura R. et al. "Dynein and the Actin Cytoskeleton Control Kinesin-Driven Cytoplasmic Streaming in Drosophila Oocytes." Development (Cambridge, England) 132.16 (2005): 3743–3752. PMC. Web. 26 May 2016.

2 Effect of charges in solution

2.1 Making V dimensionless

$$\nabla^2 V(r) = \frac{8\pi nze}{\epsilon} sinh\Big(\frac{zeV}{k_b T}\Big) \tag{2}$$

By making $\upsilon = \frac{zeV}{k_b T}$ and the screening length $\gamma = \left(\frac{8\pi n z^2 e^2}{\epsilon k_b T}\right)^{1/2}$ The equation becomes

$$\nabla^2 \upsilon = sinh(\upsilon) \tag{3}$$

The screening length is proportional to the square root of n, $\gamma \propto n^{1/2}$

2.2 Deriving the equation with the assumption that $\upsilon \ll 1$

At low limits, $sinh(x) = x^3/6 + ...$ so when $\upsilon \ll 1$,

$$\nabla^2 \upsilon = \upsilon + \frac{\upsilon^3}{3!} or \nabla^2 \upsilon = \upsilon \tag{4}$$

2.3 Steady State Case

In the steady state, $\frac{\partial \upsilon}{\partial t} = 0$. Because we know already that

$$\frac{\partial \upsilon}{\partial t} = \nabla^2 \upsilon - sinh(\upsilon) = 0 \tag{5}$$

We can easily substitute things in and find that

$$\nabla^2 \upsilon = sinh(\upsilon) \tag{6}$$

as found previously.

2.4 1-D Poisson

The linear case is exactly the same as the analytical solution as to be expected regardless of what value you make Q_0. In the non-linear case, at low Q_0, the non-linear curve resembles the linear analytical solution but as Q_0 increases, the non-linear curve displays the same curve pattern but with lower magnitudes.

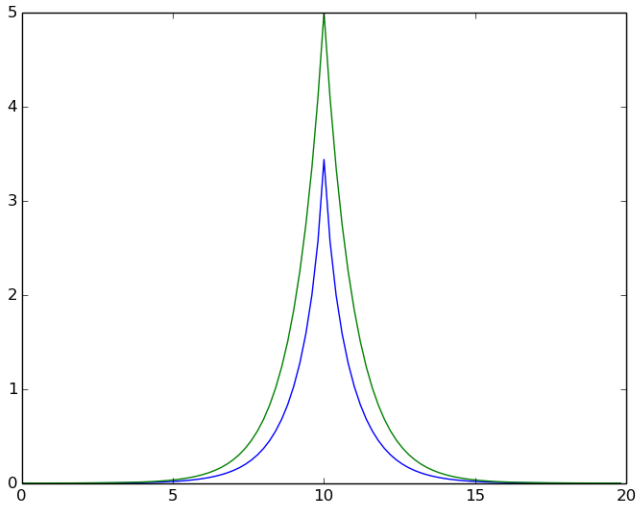

Figure 4: Linear (Green) vs Nonlinear (Blue) with $Q_0 = -10.0$

2.5 Extra Chemistry Questions

pK_a in chemistry is a scale of how acidic a substance is. pK_a is important for the stability of proteins and how enzymes interact with them.

Using an electric charge, biochemists can reduce the potential in a protein and induce an effect similar to a change in environment for the protein. By monitoring the effects on the protein, they can then use pre-existing information on pK_a and changes in pK_a to estimate different values from known patterns.

The persistence length is similar to our screening length where $\gamma \propto n^{1/2}$, where n is our ion density. Knowing this, we can infer that the persistence length is proportional to the square root of the ionic concentration.