BIOENG 455 Test 3

1 a) What are the two forces that Langevin assumed act on a particle undergoing Brownian motion in a fluid? (2 points)

A viscous drag force and a rapidly-fluctuating/random force.

b) If a particle undergoes Brownian motion in water with a diffusion constant D, how will D change if it is placed in honey and still undergoes Brownian motion? (1 point)

We have: $D = k_B T / 6 \pi \eta a$

where η is the viscosity of the solvent. As honey is thicker than water, we expect the diffusion constant to decrease.

c) What makes Brownian dynamics simulations much faster than all-atom Molecular dynamics and Dissipative particle dynamics (1 point)

We do not include the solvent particles, so there are fewer degrees of freedom to integrate.

2) What are two techniques for measuring the Brownian motion of globular proteins in live cells and state one advantage and one disadvantage of each? (4 points)

Single particle tracking

Advantages: complete trajectory, no ensemble averaging

Disadvantages: tracks may reflect distinct processes; localisation errors, stuck particle, diffusion and sub-diffusion are mixed, signal is inherently noisy, optical resolution, tracks may have gaps especially for blinking QDs

Fluorescence correlation spectroscopy

Advantages: Good statistics

Disadvantages: Needs a complex model to extract information and a dilute system

Fluorescence recover after photobleaching

Advantages: Can measure both the mobile fraction the immobile fraction; measures diffusion, reactions, conformational changes.

Disadvantages: Limited to 2 D unless a complex model is used to extract information

3) The synaptic cleft is 20 nm wide, and suppose a vesicle fuses to the pre-synaptic membrane and releases the neurotransmitter glutamate into the volume of the cleft. If the diffusion constant of the glutamate molecules is D = 1000 μm^2/sec, how long does it take them to cross the cleft? (2 point)

The cleft is a volume so we use $\langle X_2 \rangle = 6DT$, and solve for T
$T = (20\ nm)^2 / 6\ 1000\ \mu m^2/sec = 66.7\ ns$

4) What apparently contradictory effects does cholesterol have on the behaviour of phospholipids in a membrane at high concentrations? (2 points)

Cholesterol makes fluid membranes (l_d) less fluid and solid (l_o) phase membranes more fluid.

5) Name four material properties of a lipid membrane that might vary with the composition from point to point because of the large number of lipid types (2 points)

Membrane thickness, bending stiffness, area stretch modulus, fluidity (diffusivity), area per molecule

6) How does the packing parameter for a phospholipid change if one carbon chain is removed from a two-chained phospholipid assuming the length of the remaining tail stays the same? (2 points)

By definition: $p = v / a\ l$

where v = lipid volumes, a = headgroup area, and l - tail length. If we remove one tail, we expect v to decrease. So if the other terms remain the same, p will decrease as the volume has dropped.

7) State the equipartition theorem making clear its assumptions. (4 points)

Each **additive**, **quadratic** degree of freedom in the Hamiltonian of a system contributes **1/2 $k_B T$** to its internal energy **in equilibrium**; the energy is shared among all accessible degrees of freedom. If the temperature is such that some d.o.f cannot be excited, they do not contribute to the internal energy.