Homework Nano-scale Engineering #3, Due Date: March 11, 2014

Study the reference paper on "Biomolecular motors at the intersection of nanotechnology and polymer science" by Agarwala and Hessb, published in Progress in Polymer Science 35 (2010). Fill in right answers of the following statements taken from the paper. To save time, you only need to read the Sections 1, 2, 3 & 5 (pp. 253-257, 260-262). (10 points)

1. The hydrolysis of each ATP molecule causes a precise sequence of conformational and affinity changes which is coordinated between the two heads of each **kinesin** dimer. The energetic efficiency of this process can exceed **50**%, making it higher than the efficiency of a car engine.

2. The performance advantages of biomolecular motors over synthetic stimulus-responsive polymers are maintained if the motors are integrated into macroscopic structures, such as a muscle. A muscle, e.g. a biceps, contains on the order of **10^20** myosin motors coupled together into a macroscopic structure, but it still achieves a maximal efficiency exceeding **20**% . In contrast, the efficiency of energy conversion in a PNIPAM gel has been estimated as **0.001**%.

3. During polymerization, microtubules can display a phenomenon termed dynamic instability: stochastic switching between **growing** and shrinking phases on a timescale of **minutes**.

4. Fluorescently labeled tubulin and biotinylated tubulin have also been prepared and are commercially available in lyophilized form in ready-to-use aliquots (Cytoskeleton Inc., **Denver**, CO, USA).

5. Myosin motors are involved in intracellular **organelle** transport, cell movement, **endocytosis** and exocytosis, and mechanotransduction. Most importantly, myosin movement along actin filaments is the force-generating mechanism for **muscle** contraction.

6. The *in vitro* speed of purified myosin II motors at saturating ATP concentrations is about **6** μm/s, and each motor generates a force on the order of **1** pN.

7. *In vitro*, kinesin motors walk along microtubules at speeds of **1** μm/s (saturating ATP concentrations). The force at which the mean velocity drops to zero, the stall force, is about **8** pN and is **independent** of ATP concentration.

8. The approaches that have been used to design guiding tracks are: (1) physically erecting **steep** side walls for channels that guide shuttles moving on the bottom surface, (2) chemically defining track regions where motor proteins are adsorbed and surrounded by non-track regions so that shuttle motility is restricted within track regions, (3) combination of both these techniques, where only the channel bottoms

have functional motor proteins and walls do not have active motors, and active steering of shuttles using (4) **flow** fields, (5) electric fields and (6) **magnetic** fields.

9. Microtubules and actin filaments are unable to climb the sidewall and hence preferentially move in the undercut section of the channel. These **undercuts** were later combined with other **rectifier** designs for efficient guiding and generation of unidirectional motion.

10. Biotinylated kinesin has been attached to these SAMs via **streptavidin** and intermediate layers of **biotinylated** albumin. Microtubule sliding is thus confined to these tracks on the walls of the chamber.

11. However, if the **pressure-driven** shear flow is halted, the direction of filament movement becomes randomized again. Oriented filament arrays which support directed transport in the bead geometry are created by **immobilizing** the filaments immediately after alignment.

12. Guiding using magnetic fields is made possible by functionalizing filaments with **ferritic** particles.