

Solution to exercise 8:**Part 1: Molecular Mechanics of the Microtubule Network**

- 1) Given: Number MT=50; $\xi_p = 3\mu\text{m}$; T = Body Temp in K=310 K

k_B : Boltzmannkonstante; $L_c=3\mu\text{m}$;

$$k_f = \xi_p \cdot k_B T = 1.284 \times 10^{-26} \text{Nm}^2$$

$$\Rightarrow F_{buckle} = \frac{\pi^2 k_f}{L_c^2} = 1.408 \times 10^{-2} \text{pN}$$

- 2) $F_{max} = \frac{k_B T}{b} \cdot \ln([M]/[M]_C)$, $b = 8\text{nm}$, $[M] = 100\mu\text{M}$, $[M]_C \cong 5\mu\text{M}$ (Table)
 $F_{max} = 1.6 \text{pN}$

- 3) Given: $p=0.1 \text{Pa}$; $A = 4\pi r^2$; $r = 3\mu\text{m}$; $F_{tot} = p \cdot A$

$$A = 113 \times 10^{-12} \text{m}^2 = 113 \mu\text{m}^2$$

$$F_{tot} = 11.3 \text{pN}$$

$$\frac{F_{tot}}{F_{buckle}} \cong 800 \text{MT} \quad (\text{not physiological, too many MT})$$

- 4) Given: $\xi_p = 2x \xi_p \Rightarrow k_f = 2 \cdot 1.284 \times 10^{-26} \text{Nm}^2 = 2.57 \times 10^{-26} \text{Nm}^2$

F_{tot} is the same, L_c is the same, F_{buckle} is the double:

$$\#MT = 400$$

Note: Physiologically, the MT tend to be kept both short and focused to maximize their propulsive force when required, for instance in the mitotic spindle used for cell division.

Part 2: Additional Questions on the Cytoskeleton

2.1 **Which of the following cytoskeletal elements is directly involved in active protein transport?**

- a) Integrins.
- b) Microtubules emanating from the centrosome.
- c) Actin filaments at the cell leading edge
- d) Focal adhesion anchored myosin II.
- e) — All of the above.

a) Integrins are transmembrane proteins through which the cell cytoskeleton is anchored to cell binding sites of the extracellular matrix. b) Although other cytoskeletal proteins can also be used in intra-cellular transport, the micro-tubule network is especially important – providing rails upon which molecular motors (kinesin, dynein) can carry loaded cell organelles. c) actin filaments at the leading edges are mostly important for cell movement d) the acto-myosin motors at focal adhesions are mostly important for generating cell tension and pulling on the extra-cellular matrix.

2.2 **Protrusive forces enabling advance of the cell leading edge is mostly generated by**

- a) Polymerization of actin biopolymer chains.
- b) Actomyosin motors anchored at focal adhesions.
- c) Dynamic regulation of the cell membrane stiffness.
- d) — All of the above
- e) — None of the above

Although all of the listed activities play a role in cell motility and migration, the leading edge movements of a cell are most heavily driven by polymerization of actin.

2.3 **Which of the following molecular motor / function pairs are/is correct?**

- a) Myosin / directional transport on the microtubule network
- b) Kinesin / tension applied to the actin network
- c) Dynein / directional transport on the microtubule network
- d) — All of the above motor/function pairs are correct

- e) — None of the above motor/function pairs are correct

Myosin motors require a “fixed” actin substrate, and are primarily employed in cells and tissues to generate contractile forces. Kinesin and dynein both interact with microtubules, with kinesin moving away from the centrosome (typically from the nucleus toward the outside of the cell), and dynein moving toward the centrosome (typically toward the nucleus). These motor/scaffold pairs are essential for intracellular transport.

Part 3. Cell cycle & Mitosis

3.1 The goal of the mitosis (cell division) is to produce daughter cells, which

- a) are genetic identical with their mother cell.
- b) have the same number of chromosomes as the mother cell, but different genetic dispositions.
- c) have half of the chromosomes as their mother cell.
- d) No answer is correct.
- d) All answers are correct.

3.2 Sister chromatids

- a) are produced by the DNA replication.
- b) are connected via the Centromere before cell division.
- c) are separated during Mitosis.
- d) are identical copies of DNA.
- e) None of the above
- e) All of the above

3.3 How many maternal Chromosomes does a human cell have during the G1 phase?

- a) 23
- b) 46
- c) 92
- d) 184

3.4 «Cytokinesis» is ...

- a) The division of nucleus.
- b) The division of the cytoplasm.
- c) the replication of chromosomes.
- d) None of the above.
- e) All of the above.

3.5 Which one of the following statements is not correct?

- a) In the Prophase the chromosomes condense.
- b) The chromosomes align at the equator of the cell during the Metaphase.
- c) During the Telophase the Chromosomes decondense.
- d) The nuclear envelope decays during the Metaphase.

Part 4. Stem Cells**4.1 Which one of the following statements is not correct about embryonic stem cells?**

- a) Embryonic stem cells are totipotent.
- b) Embryonic stem cells can differentiate into all cell types.
- c) Embryonic stem cells are cells derived from the early embryo
- d) Adult stem cells are better suited to develop basic mechanisms of organ and tissue development as embryonic stem cells.