BMT-72106 CELLULAR BIOPHYSICS: EXERCISE 3 CELLULAR INTERATIONS

Qin He

272486
qin.he@tuni.fi

ABSTRACT

This week's exercise covers the interations among cells.From the concept of tight junctions, adherens junctions and desmosomes, we also look into the tensegrity model and the related calculation upon Young's module and rigidity gives as the quantative sense of the microtubule buckle when force reaches critical force. The last two exercise are about the single ion and multi ions keeping 0 net currets which are well known for the Nerst Equation and Goldman Equation. It might be the introduction to the coming study of Hodgkin Huxley which might also helpful to our project.

1. EXERCISE 1 DESCRIPTION OF CONCEPTS

Please, describe shortly a) Tight junctions Tight junctions in a narrow band can seal their adjacent epithelial cells beneath their apical surface, consisting a network of claudins and other proteins. They function as 1) limiting the passage of molecules and ions through the space between cells. This provides thigher control over what substances are allowed through; 2)blocking the movement of integral membrane problems between the apical and basolateral surfaces of the cell. Thus the special functions of each surface can be preserved.

b) Differences between adherens junctions and desmosomes 1)Although they are both common in epithelia, they locate at different places. Adherens Junctions are built from cadherins and catenins connected to actin filaments while doesmosomes are localized patches attached to intermediate filaments of ketarin in the cytoplasm. 2)They function also differently. Adherens junctions provide strong mechanical attachments between adjacent cells, holding cardiac muscle cells tightly together as the heart expands and contracts as well as epithelia cells. They might also be responsible for contact inhibition and are present in narrow bands connecting adjacent cells or present in discrete patches holding the cells together. In contrast, Demosomes are related to pempigus which is an autoimmune disease in which the patient has developed antibodies against protains in desmosomes. The loosening of the adhesiion between adjacent epithal cells causes blistering.

c) Tensegrity model in the context of mechanobiology The central hypothesis of the cellular tensegrity model established that some components of the cytoskeletal network are under tension and that these forces are balanced by other cellular components under compression. The tensegrity model represents the cell as a mechanically stable structure, composed of compression-bearing struts and tension-bearing cables. The cables create an initial pre-stress in the cell model, which is resisted by the structs, in order to maintain a system in mechanical equilibrium. THe physiological parallels to these compressive elementss are physiological representaition of the cables, which resist tensional loads. The tensiegrity model commonly consists of a six-struct structure, with twenty-four cable segments. For each struct-cable interconnection point, equilibrium equations can be written to describe the resultant motion of the tensegrity structure, when an externeally applied entile force is acting upon it. It can be used to predict the linear relatonhip between cellular pre-stress and cell stiffness seen in experiments, and stress-dependent spatial rearrangement of cell structures. They can also be used to elucidate mechanotreansduction pathways and have been adapted to allow for tensegrity structures of higher complexity and enhanced physiological relevance.

2. EXERCISE 2 MICROTUBULE STIFFNESS

Bending stiffness measures the flexural rigidity of a rod-like structure such as a microtubule. Flexural rigidity is calculated as EI, where E is the Youngs modulus and I is the geometrical moment of inertia. Microtubule can be approximated as hollow tube as shown in Figure 2, whose geometrical moment of inertia about the axis through the middle of its cross-section is According to table, the average of $P_{cr} * L^2$ is $5.931626 * 10^8 nm^2 * pN$, And:

$$I = \pi * (D_0^4 - D_i^4)/64$$
$$= \pi * (25^4 - 17^4)/64$$
$$= 5503.266 nm^4 * \pi$$
$$P_{cr} = \pi^2 * E * I/L^2$$
$$E = P_{cr} * L^2/(\pi^2 * I)$$

$$I_z = \pi \frac{D_o^4 - D_i^4}{64}, \tag{1}$$

where D_o and D_i are the outer and inner diameter of the hollow cylinder, which for microtubules are around 25 nm and 17 nm, respectively. If microtubules are compressed, they will buckle when the

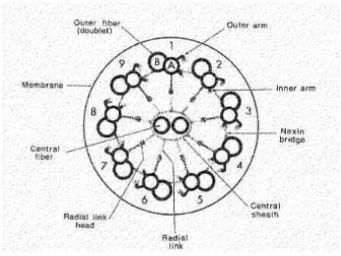

Figure 1: Cross-sectional view of a microtubule.

compression force reaches critical force P_{cr}, which can be calculated with Euler's formula:

$$P_{cr} = \frac{\pi^2 EI}{L^2}, \tag{2}$$

where L is the cylinder length. Table below gives critical forces measured of microtubules with varying lengths. Based on these results, calculate the mean flexural rigidity and Young's modulus for microtubules.

Fig. 1. cross-sectional.

$= P_{cr} * L^2/(5503.56nm^4 * \pi^3)$
$= 3476pN/nm^2$
$meanrigidity = 3476pN/nm^2 crossproduct 5503.266nm^4 * \pi$
$= 6.01 * 10^{13} pN * nm^2$

3. EXERCISE 3 NERST POTENTIAL

Exercise 3. *Nerst potential*
Nernst potential can be written as:

$$E = \frac{RT}{zF} \ln \frac{[\text{ion outside cell}]}{[\text{ion inside cell}]} \tag{3}$$

a) What phenomena does the equation above describe? What do the symbols denote?

The table below lists typical concentrations and permeabilities of the ions in a mammalian neuron.

b) Calculate the Nernst potentials for K^+, Na^+ and Cl^- at 37 °C using the values in the table.

Ion type	Intracellular concentration (mM)	Extracellular concentration (mM)	Permeability of the membrane
K^+	140	5	1
Na^+	10	145	0.05
Cl^-	6	110	0.40

a) It is the equation relates to either reduction potential of an eletrochemical reaction(half-cell or full cell). Here, its application on physiology is that it calculate the potential of an ion of charge z across a membrane, determined by the concentration of the ion both inside and outside the cell. Because the membrane potential must be equal to the Nernst potential, which means in this status, the part of the ion fluid get outside the cell causing the current equals the part getting into the cell balance the current back to net zero. R stands for the ideal gas constant(J/K), T is the temperature in K. The F is the Fraday's constant which equals to Na*q and the ratio of the concentration of the ion at outside and inside the cell.
b)$E_k = 8.315 * (37 + 273.15)/(9.65 * 10^4 * 1) ln(5/140)$
$= -0.09J$
$E_{Na} = 8.315 * (37 + 273.15)/(9.65 * 10^4 * 1) ln(145/10)$
$= 0.07J$
$E_{Cl} = 8.315 * (37 + 273.15)/(9.65 * 10^4 * 1) ln(110/6)$
$= 0.08J$

4. EXERCISE 4 GOLDMAN EQUATION

The Goldman equation can be written for K^+, Na^+ and Cl^- in form

$$E_{K^+,Na^+,Cl^-} = \frac{RT}{F} \ln \left(\frac{P_{Na^+}[Na^+]_{out} + P_{K^+}[K^+]_{out} + P_{Cl^-}[Cl^-]_{in}}{P_{Na^+}[Na^+]_{in} + P_{K^+}[K^+]_{in} + P_{Cl^-}[Cl^-]_{out}} \right) \tag{4}$$

Fig. 3. Goldman.

a)The Goldman equations describe quite similar phenomenon about the total net current being unchanged from resting potential to action potential. However, because it has three different ions, the total balance is kept through different ions with the flow of negative ions causing currents and positive ions balancing it back. The P is the Pion which stands for the permeability of certain ion, extent of move out of the cell(or into the cell). b)$E = 8.315 * (37 + 273.15)/(9.65 * 10^4 * 1) ln((0.05 * 145 + 1 * 5 - 0.4 * 6)/(0.05 * 10 + 1 * 140 - 0.41110))$
$= -0.012J$
The result shows the potential change in total under Goldman equation which determines the resting potential is negative while the sum of each channel in the previous exercise is positive. This tells us that the potential do not have additive properties as a system with K^+,Cl^-,Na^+. Again also supports the fact that although the net current is zero but it is different from in the equilibium. c)The potential becomes positive which value is 0.017J. It is not that realistic since the Nerst potential also holds for the sodium. If one side of the move of sodium suddenly increases, its opposite side should also increases to balance the current and thus the change of the permeability usually cost more time and energy.